Okatie River Watershed Management Plan
Final Report

Prepared for

South Carolina
Department of Health and Environmental Control
Office of Ocean and Coastal Resources Management

Prepared by

Applied Technology and Management, Inc.
7 Commerce Place
Bluffton, SC 29910

Prepared with funding from
The National Oceanic and Atmospheric Administration through
The South Carolina Department of Health and Environmental Control,
Office of Ocean and Coastal Resource Management,
NOAA Award #NA970Z0198

August 29, 2002
01479

APPENDICES

LIST OF TABLES

List of Figures

LIST OF GRAPHS

1.0 INTRODUCTION

1.1 Background and Purpose

The Okatie River watershed is located in Beaufort County and Jasper County, South Carolina. Approximately 80 percent of the 24.6 square mile watershed is within Beaufort County. Various tributaries feed into the Okatie River, which flows in a northern direction until a major bend in the river near the Camp St. Mary Road. At this bend, the direction of the river changes toward the southeast to the confluence of the Colleton River, approximately one mile downstream. The Okatie River is a tidally influenced river that supports shellfish populations. The location of the Okatie River watershed study area is shown on Figure 1-1.

This study uses and builds upon the information, data, inventories and results of pertinent studies and data compilations. However, as opposed to a flood study, the purpose of the present study is to prepare a comprehensive watershed management master plan for the Okatie River watershed in which water quality as well as water quantity issues are addressed. The result of the management plan will be recommendations and a reference for future development and Best Management Practices (BMPs). Of primary concern, the Okatie River watershed is an area that has experienced rapid growth and subsequent water quality degradation. Applied Technology and Management, Inc. (ATM) was contracted under the Scope of Services to do the following:

- To gain understanding of the present water quality and quantity conditions in the Okatie watershed.
- To review both water quantity and water quality research and literature that have been done and other associated regional literature resources.
- To determine specific water quality problem location areas within the Okatie basin and their respective outlier parameters.
- To analyze the extent of outlier water quality parameters.
- To address the possible causes of impaired water quality data and provide solutions to these problems.

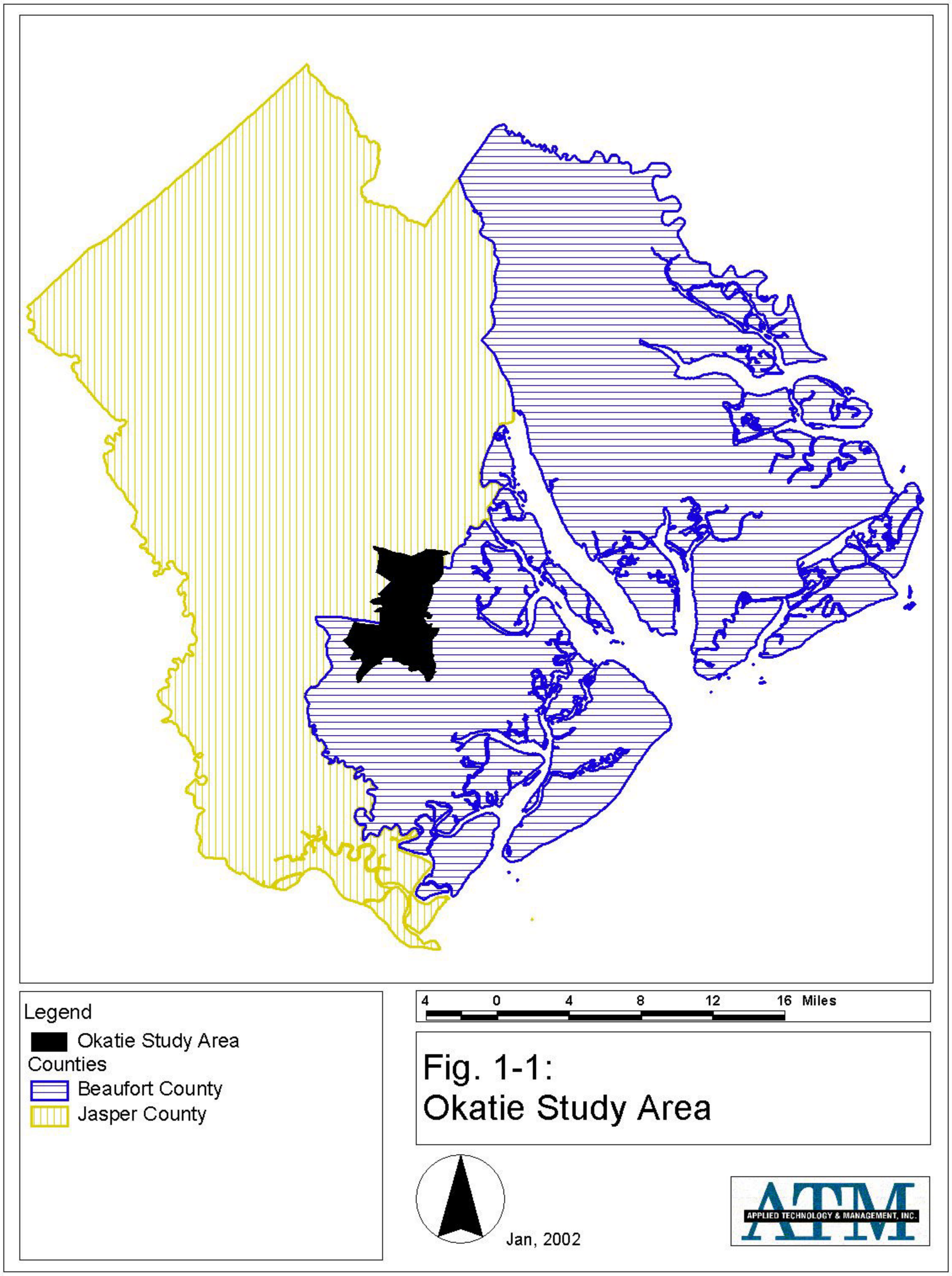


Fig. 1-1:
Okatie Study Area

- To evaluate the effectiveness of stormwater management design and operational practices that currently exists in the watershed.
- To provide improvement of stormwater standards for new developments in rural areas and priority growth areas.
- To provide a definition of important headwater areas and the development of additional measures to protect the upper reaches of tidal creeks.
- To provide solutions that include recommendations for non-structural and structural BMPs, monitoring, and an alternatives evaluation.
- To provide for a reduction of existing flooding (if any) and a minimization of economic and social losses.

Seven tasks were completed to fulfill the above goals of this study and were performed as per the South Carolina Department of Health and Environmental Control (SCDHEC) contract effective February 21, 2001. These tasks include Data Collection and Processing, Stormwater Quantity Evaluations, Stormwater Quality Evaluation, Alternatives Evaluations, Recommendations, Watershed Management Plan Preparation, and a Watershed Management Plan Guidance Document.

Task 1. Data Collection and Processing

- **Topography and photography** were collected and are comprised of various survey data, including: 1994 and 1999 aerial photography, U.S. Geological Survey (USGS) quadrangle maps, planned unit development (PUD) plans, U.S. Department of Transportation (USDOT) drawings, and various geographic information system (GIS) layers obtained from SCDHEC and the South Carolina Department of Natural Resources (SCDNR).
- **Rainfall** data were gathered from the U.S. Natural Resources Conservation Service (NRCS) and the National Climatic Data Center (NCDC) as compiled by EarthInfo, Inc. and Hydrosphere, Inc.
- **Hydrologic data evaluation** was done by utilizing the selected model and by referencing to various PUD analyses. No stream gauges were placed in the river to check stage calculations. Tidal information was included in the evaluation.
- **Water quality data evaluation:** Water quality data were collected from the U.S. Environmental Protection Agency's (EPA's) STORET database and from Beaufort County. The data primarily concentrated on bacteria, as indicated by

fecal coliform (FC). Investigations into the following parameters were also compiled and summarized from literature research: Five-day Biochemical Oxygen Demand (BOD-5), Total Kjeldahl Nitrogen (TKN), Ammonia/ammonium (NH3/4), Total Phosphorus (TP), Invertebrates, Trace Metals and Polyaromatic Hydrocarbons (PAHs). Water quality data were collected from the EPA's STORET database and from Beaufort County. Additionally, pollutant loading estimates were performed for the PLU and FLU conditions for total suspended solids (TSS), TP, BOD, FC and zinc (Zn).

- **Soils** data were compiled from the NRCS National Soil Survey Center GIS data clearinghouse and downloaded into ArcView GIS for analysis.
- **Present land use (PLU) and future land use (FLU)** was delineated using photo-interpretation and field verification. Future land use was determined from approved PUDs and zoning information obtained from the Beaufort County Engineering and Planning and Zoning Departments, and the Lowcountry Council of Governments (LOWCOG).
- **Structural and stormwater management facilities** were inventoried and surveyed by NRCS and field reconnaissance. Areas in need of possible repair were listed. Information for facilities located within private developments was obtained from PUD plans.
- **Complaint files and problem areas** were investigated with conversations from South Carolina Department of Transportation (SCDOT), NRCS, Beaufort County Planning and Zoning, and the former Beaufort County Public Works Director (Chris Eversmann). They indicated that there were no outstanding problem areas in the watershed. Additionally there were no subsequent complaint files. The SCDHEC Low Country District Environmental Quality Control (EQC) office and Office of Ocean and Coastal Resource Management (OCRM) were also contacted for complaint files. Beaufort County Stormwater Management Master Drainage Plan, prepared in 1995 had a special projects summary; however, none of these projects were in the Okatie River Watershed.
- **Regulatory framework** was summarized for local, state, and national regulations.
- **Level of service (LOS) – flood protection and receiving water protection:** The LOS for recent and new development is determined by regulations in Beaufort County by the Beaufort County and state (SCDHEC) regulations. All new developments are to be designed under the requirements listed in the

Beaufort County Manual for Stormwater Management (1998). Level of service standards for new development in Jasper County are based on the state SCDHEC requirements and are variable for size and location of development, the type of BMP used and distance from receiving waters. The state requirements for the treatment of stormwater runoff are typically less restrictive than Beaufort County regulations.

- **Hydrologic and hydraulic data:** The following were collected and processed for the purpose of watershed and catchment modeling:
  - Sub-watershed area delineations
  - Hydrologic overland flow data
  - Stage area relationships for storage facilities
  - Boundary conditions
  - Open channel data
  - Culvert and bridge data

Task 2. Stormwater Quantity Evaluations

- **Model Selection:** The XP-SWMM (Storm Water Management model) version 2000 was selected to perform water **quantity** analyses of the watershed and the sub-catchments. The following subtasks were performed:
  - Input data set preparation for PLU and FLU
  - Model calibration/verification
  - Computer simulations for the 2-, 5-, 10-, 25-, and 100-year, 24-hour storm events for PLU and FLU
  - Identification and prioritization of problem areas

Task 3. Stormwater Quality Evaluation

- **Model Selection** The XP-SWMM 2000 model was utilized in the development of a pollutant loading continuous simulation model that utilized long-term rainfall patterns. Pollutant loading estimates for BOD-5, TP, TSS, FC, and Zn were performed for both PLU and FLU.
- **Input data set preparation** utilized the 1998 Beaufort County BMP manual event mean concentrations (EMC) chart for different land use types. These EMCs, including estimated BMP coverages, were entered into the XP-SWMM model for PLU and FLU to develop pollutant-loading estimates.

- **Identification and prioritization of problem areas** were done by noting outlier sampling stations from the water quality data gathered from the STORET database. This information was input into Microsoft Excel for statistical and trend-line analysis. Additionally, the pollutant loading estimates were utilized in the determination of potential water quality problem areas. Prioritization was based on highest pollutant loading levels.

Task 4. Alternatives Evaluations

Conceptual alternative approaches were developed and evaluated for existing and future stormwater problems. The alternatives provide general characteristics of conveyance, storage, and treatment requirements to meet the LOS goals established with the County and SCDHEC. The potential use of and location for regional stormwater facilities are reported. The following general alternatives were evaluated:

- PLU with improved maintenance
- PLU with structural modifications
- FLU with non-structural BMPs and structural modifications
- FLU with additional modifications

Task 5. Recommendations

Recommendations for watershed management include suggestions for development review, BMPs and regional facilities. Costs and benefits are included, as is an analysis of the potential economic impacts of the recommended approach, sequence, and timing for implementation. These recommendations include:

- The location of regional structural improvements
- Potential funding sources that are available for implementation of the study recommendations
- Design criteria and BMPs to reduce and prevent long-term water quality degradation

Task 6. Watershed Management Plan Preparation

- The specific tasks, and the methodologies used to perform each task, as well as the results, evaluations and subsequent recommendations comprise the Watershed Management Plan. The following items are included in the report:
    - Problem discussion and study goals

- Background
- Methodologies used
- Data collection and evaluation
- Water quantity evaluations
- Water quality evaluations
- Alternatives evaluations
- Recommendations for non-structural and structural BMPs
- Operations and maintenance
- Monitoring
- Funding sources
- Implementation schedule

Task 7. Watershed Management Plan Guidance Document

The guidance document provides guidelines for future watershed studies in the remaining watersheds of Beaufort County. The format will be useful to the Beaufort County Stormwater Utility. It provides guidance on LOS anticipated for other watersheds and addresses water quantity and quality data requirements, water quantity and quality evaluation methods, level of detail, presentation of results, suggested scenarios for alternatives evaluations, master plan requirements, report requirements, surveying, photographic and photogrammetric needs, and specifications for future studies.

1.2 Problem Overview

The Okatie River watershed is experiencing rapid growth. This is illustrated by a comparison of Figures 1-2 and 1-3, which present photographs of the study area from 1994 and 1999. These photographs illustrate the shift in land use from rural and silviculture toward residential and golf course communities, and commercial development.

Administrative closures of shellfish beds for harvesting in Beaufort County have occurred due to the high bacterial FC counts [>14 colony producing units per 100 milliliters (CPU/100mL)] as consumption of these shellfish may pose a threat to human health. Approximately 46,000 acres in Beaufort County alone have been closed in the recent past to harvesting (SCDHEC, 2000). In the Okatie River watershed (an Outstanding Resource Water), the upper reach of the Okatie is a restricted shellfish harvest area (Beaufort County GIS Department; Payne, 2001) and the headwaters were classified as

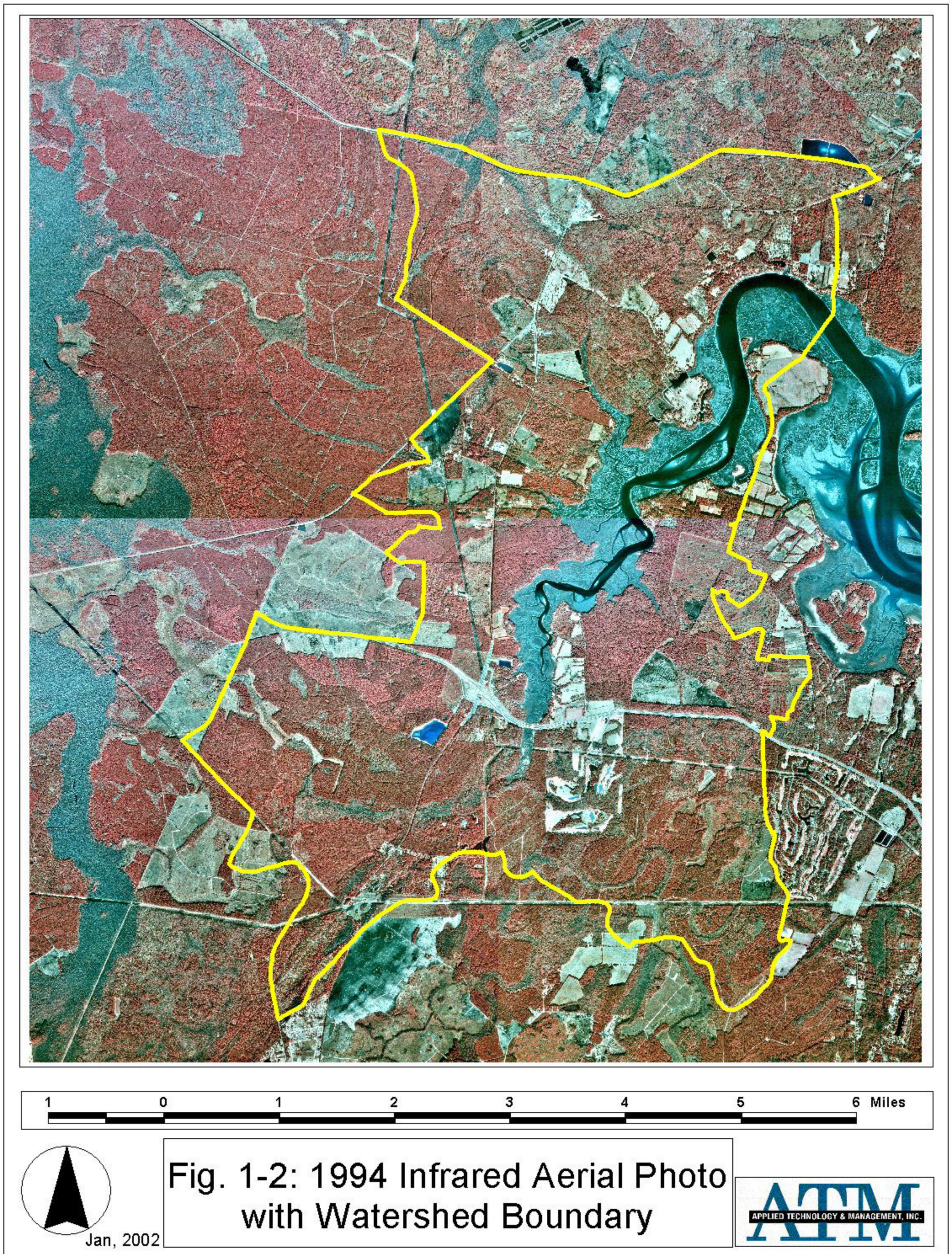


Fig. 1-2: 1994 Infrared Aerial Photo with Watershed Boundary

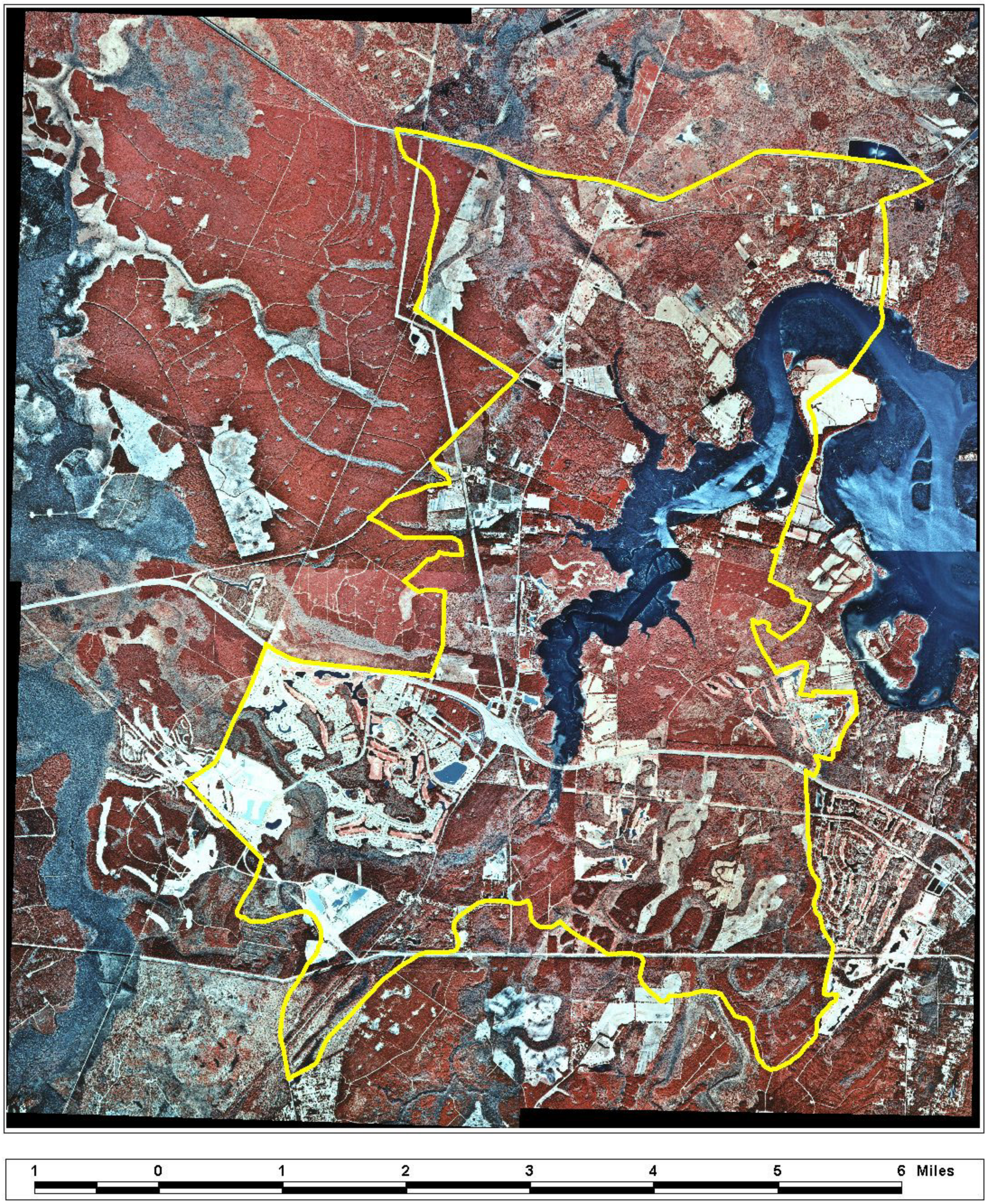


Fig. 1-3: 1999 Infrared Aerial Photo with Watershed Boundary

Jan, 2002

prohibited in 1996 [Clean Water Task Force (CWTF), 1997]. Because there are correlations between degree of urbanization and amount of contaminants in the watershed (SCDHEC, 2000; Say-Hua Lim, 1982; CWTF, 1997), more effective BMPs are now emphasized to minimize water quality degradation.

As might be expected, water pollution in the estuaries of South Carolina is concentrated in the areas of greatest industrial and urban development. Water use, land use, and discharge practices result in an uneven distribution of chemicals, eutrophication, oxygen depletion, turbidity, and other conditions detrimental to life in estuarine and marine ecosystems. Environmental impacts from pollutants vary with the type of pollutant, the biota at risk, and other factors such as temperature, salinity, and pH (-log[H_3O+]).

1.3 Physical Description

The Okatie River is a narrow, long, poorly flushing tidal creek with freshwater input at the headwaters (CWTF, 1997). Approximately 80 percent of the 24.6 square mile Okatie River watershed is located within Beaufort County. Various tributaries feed into the Okatie River, which flows in a northern direction until a major bend in the river near the Camp St. Mary Road. At this bend, the direction of the river changes toward the southeast until the confluence of the Colleton River, approximately one mile downstream. Tides in this area are semidiurnal, consisting of two low and high tides each lunar day. Mean tidal range is 5.9 feet during normal tides and 6.9 feet during spring tides. The greatest tidal ranges of the year typically occur around full moon during the months of September through December. There is considerable variation in the normal tide range due to the prevailing strength and direction of winds (Payne, 2001).

The Okatie River watershed is an area that has experienced rapid growth and subsequent potential water quality degradation. As the amount of impervious surface increases, there is the potential for corresponding increases in the volume of stormwater runoff reaching the Okatie River, as forest and agricultural land is converted to residential and commercial use.

1.4 Data Collection and Processing

A compilation and evaluation of available baseline information on physical and water quantity and quality characteristics of the watershed was performed and includes the following information.

1.4.1 Topography and Photography

Initial topographical information was obtained from the 1:24000 scale USGS quadrangle map with five-foot contours. Much of the survey-quality baseline data on topography, ditches, canals, culverts, and other drainage infrastructure components were obtained by an ongoing interactive process between NRCS, which provided field survey services, and ATM. These survey data were necessary because of the lack of pre-existing data and the recent stormwater routing improvements related to development. Survey data included reference benchmarks, ditch and stream cross sections, culvert inflow/outflow invert elevations, culvert dimensions, centerline-of-road elevations at culvert crossings, upstream and downstream culvert cross sections, stormwater pond dimensions and control devices, and flow directions. Digital photos of ditches and culverts were used in the documentation of drainage infrastructure status.

Additional survey data were compiled from Beaufort County Planning and Zoning Departments, and Beaufort County Engineers Office's files of PUD development plans. Development plans were available from Grandee Oaks, Oldfield, Berkeley Hall, Sun City, Eagle Point, Okatie Center, Rivers End, and Island West PUDs. The Oldfield and Berkeley Hall PUDs had newly surveyed data taken from NRCS but these elevations are expected to change due to future construction. There were no files for Willow Run PUD. Additionally, the Buckwalter PUD plan is in its planning stages with the town of Bluffton and is not available. Where development was expected to be completed soon, design elevations as contained in the PUD master plans were used for analytical purposes.

The SCDOT provided road survey data. Because of the recent road improvements to State Road 170, it was necessary to compile this information at strategic water crossings. Some new survey information was also obtained by the NRCS surveyor to verify undocumented drainages.

False color infrared orthophotos from 1994 (Figure 1-2) and 1999 (Figure 1-3) were obtained from the GIS data clearinghouse at SCDHEC. These were imported to

ArcView GIS and printed as poster-sized photos for easy accessibility. The photos were used in land use characterization and drainage network construction activities. Land development occurring in the 5-year period between 1994 and 1999 is clearly evident in comparing the two photos. The 1999 photo (see Figure 1-3) was primarily used as the most recent representation of PLU.

1.4.2 Rainfall

Rainfall data were obtained from the NCDC database, as compiled by Earthinfo, Inc. and Hydrosphere, Inc. The data obtained included daily rainfall volumes from the nearby Beaufort Waste Water Treatment plant, Savannah Airport, Yemassee, and Hilton Head, South Carolina. High loading events that were determined from various water quality studies discussed below had their respective rainfall antecedent conditions determined from the Hydrodata database. These rainfall data were compiled to develop 7-day antecedent conditions for sampling events (see Appendix 1, Section A). The antecedent conditions were summed for each data collection point and compiled to average the rain event for each day. The week antecedent average values were also summed. These hydrologic data were obtained to determine if the high loading events were due to flushing effects. Hourly and 15-minute precipitation data were obtained from Savannah International Airport as compiled by Earthinfo, Inc. These data were used in the continuous simulations for generating pollutant-loading estimates for each catchment.

The total rainfall volume for the design storms was determined using NRCS Technical Release (TR) 55 (Watershed Modeling Systems). The total volumes used in this report are 4.5, 5.9, 6.8, 7.8, and 10.0 inches for the 2-, 5-, 10-, 25- and 100-year design storms respectively. This rainfall is distributed using the Soil Conservation Service (SCS) Type III distribution.

1.4.3 Hydrologic Data Evaluation

Hydrologic data were utilized from PUD reports to provide guidance for future computer simulations. There are no stream gauges in the Okatie watershed that would provide suitable data for formal model calibration. Tidal information was gathered from the computer software package, Tides and Currents for Windows™. These data were then converted to subsequent elevations using the National Oceanic and Atmospheric Administration (NOAA) benchmark database.

1.4.4 Water Quality Data Evaluation

Water quality data were gathered from the EPA's STORET database. Monitoring reports from the Eagle Point PUD monitoring program were also obtained. The data were analyzed for summary statistics, temporal trends, and spatial patterns. Details of this evaluation are presented in Section 4.

1.4.5 Soils

The soils data were compiled from the NRCS national soil survey center and the electronic format was downloaded into ArcView GIS. The source for the data was the U.S. Department of Agriculture (USDA)-NRCS Soil Survey for Beaufort and Jasper Counties. The map units, or the soil types found in the survey area, were each assigned a reference code and a color code. These data were incorporated into ArcView GIS software, combined with the catchment delineations. Color-coded sub-basin soils maps of the study area were then generated. Figure 1-4 shows the soils in each sub-watershed by soil name. Figure 1-5 displays the soils by type. The soils in the Okatie Watershed are predominately fine sand, fine sandy loam, loam, and loamy fine sand. The soil names in the study area are listed in Table 1-1.

Table 1-1. Soil Names In The Okatie Watershed

Argent	Okeetee
Argent-Okeetee	Onslow
Baratari	Paxville
Bertie	Polawana
Bertie-Coosaw-Tomotley	Ridgeland
Bladen	Rosedhu
Bohicket	Santee
Borrow Pit	Seabrook
Cape Fear	Seewee
Capers	Tomotley
Chisolm	Wahee
Coosaw	Wando
Deloss	Water
Eddings	Williman
Eulonia	Yemassee
Murad	Yonges
Nemours	Yonges-Argent

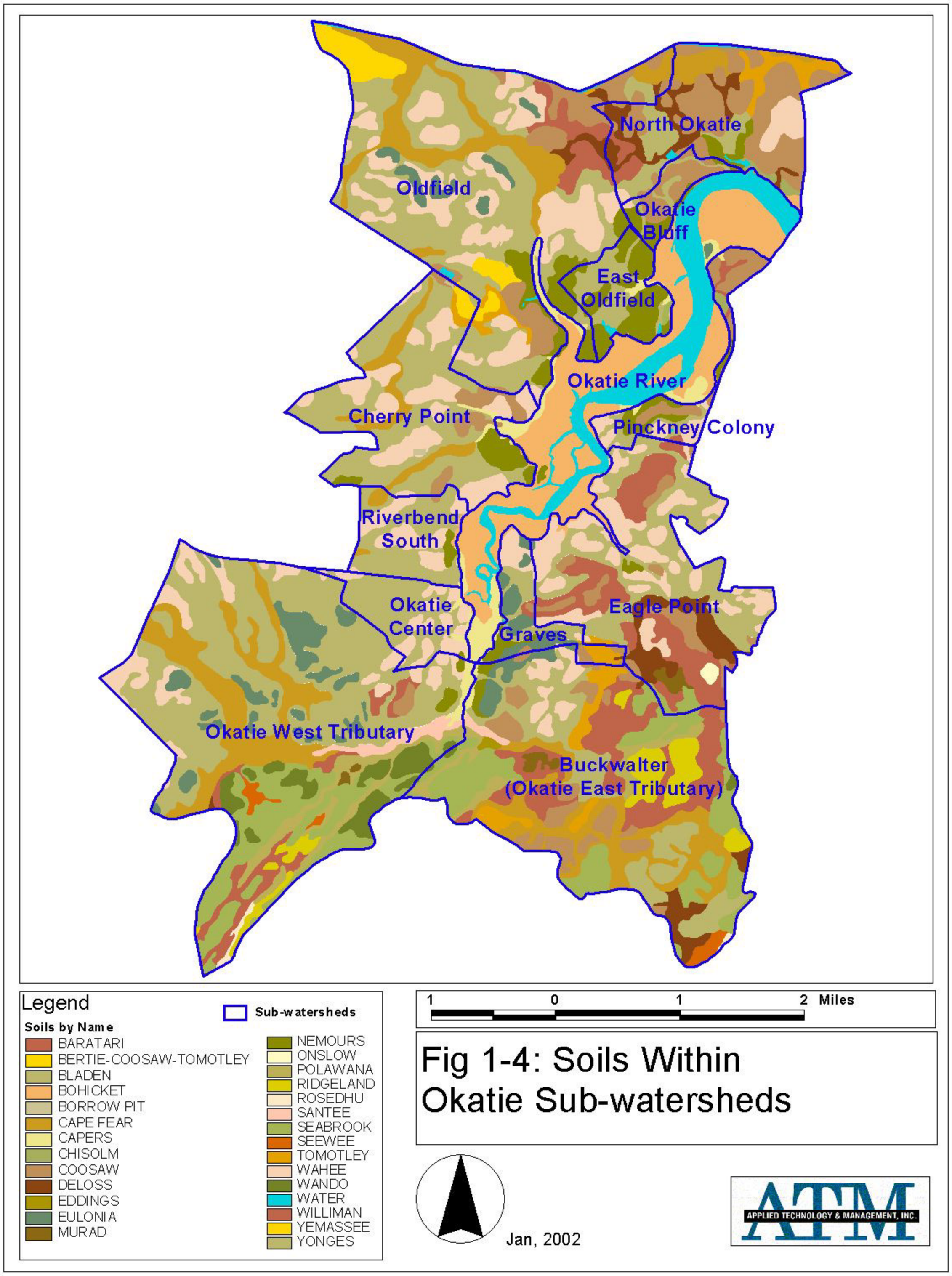


Fig 1-4: Soils Within Okatie Sub-watersheds

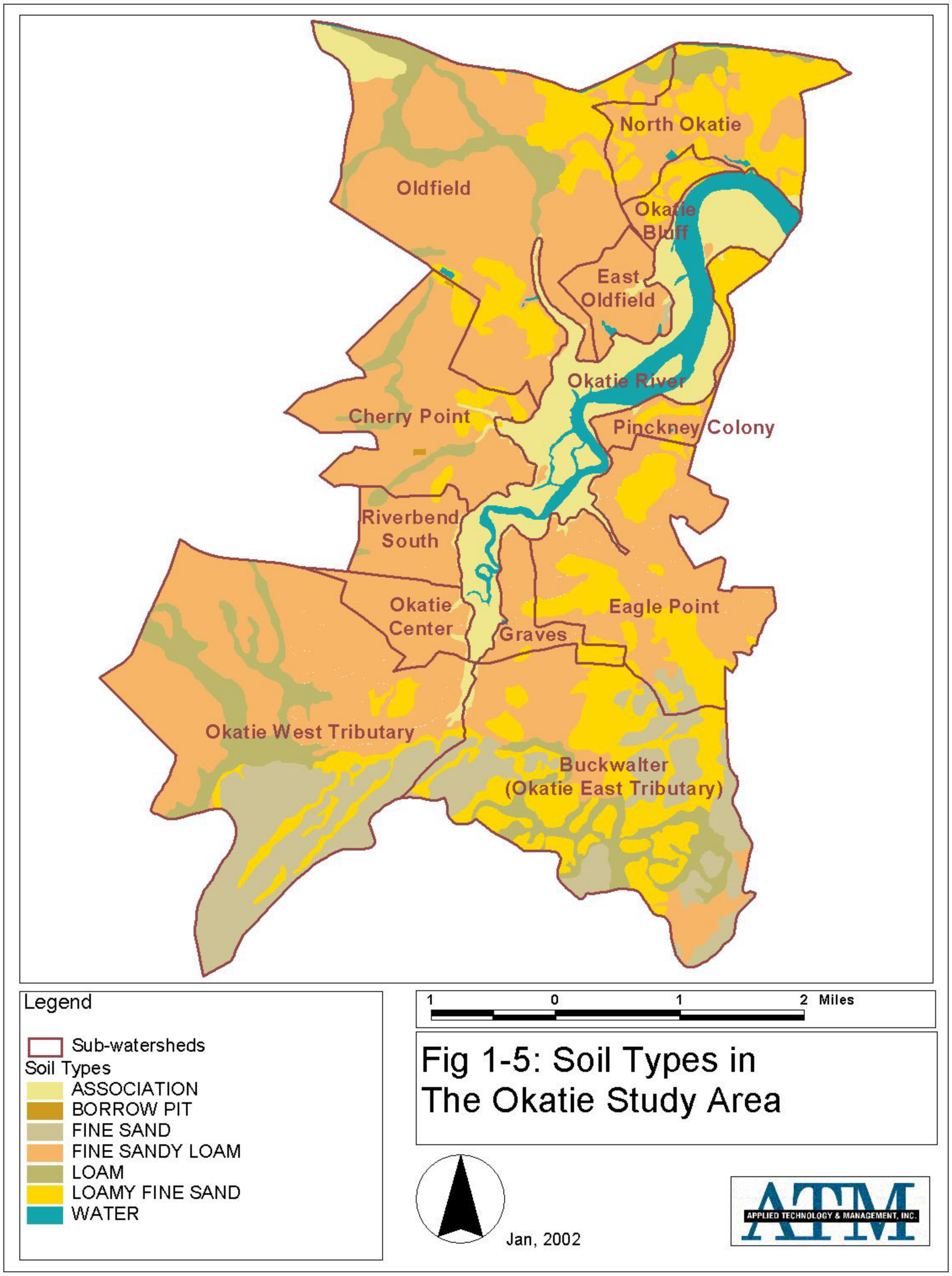


Fig 1-5: Soil Types in The Okatie Study Area

The SCS Soil Survey for Beaufort and Jasper Counties classification of hydrologic soil group (HSG) for each soil was used to estimate runoff from each land use category. A hydrologic soil group refers to soils grouped according to their runoff producing characteristics. Soils are typically assigned to four groups. Group A soils have a high infiltration rate when wet and low runoff potential. They are mainly deep, well drained, and sandy or gravelly. On the other extreme, Group D soils have a very slow infiltration rate and a high runoff potential. They have either a clay pan layer at or near the surface, permanent high water table, or shallow impervious bedrock layers.

The hydrologic soil groupings are shown on Figure 1-6. The overall percentages of each hydrologic soil group within the watershed are shown in Table 1-2. Approximately 97.6 percent of the soils within the watershed are classified as having a high runoff potential (HSG type D, C, B/D, and A/D). The majority of the soils (12,343 acres or 81.8% of land) in the watershed are Class D soils. Approximately 2% of the watershed area is HSG A, which is predominately in the southwestern portion of the watershed. A soil is assigned to two hydrologic groups (i.e., A/D and B/D) if the HSG of the soil can be altered through internal drainage. These dual classifications comprise approximately 3% of the watershed area at the time of the survey in 1980. In this study, due to limited drainage improvements and small drainage densities, all SCS hydrologic soil groups with classification of A/D or B/D were treated as one soil type, Group D, which provides for a more conservative analysis (i.e., more runoff).

Table 1-2 Hydrologic Soil Group Distribution

Hydrologic Soil Group	HSG Area	% of Watershed Area
A	228.13	1.50
B	129.56	0.85
C	2034.86	13.38
D	12343.477	81.18
A/D	101.62	0.67
B/D	368.34	2.42
total land area	15205.99	

Note that a 107-acre area in the northwest corner the Oldfield sub-watershed is classified as a Bertie – Coosaw – Tomotely soil and may act as a Class B, D, or B/D, depending on soil type encountered. This area is within a low-lying topography and, z

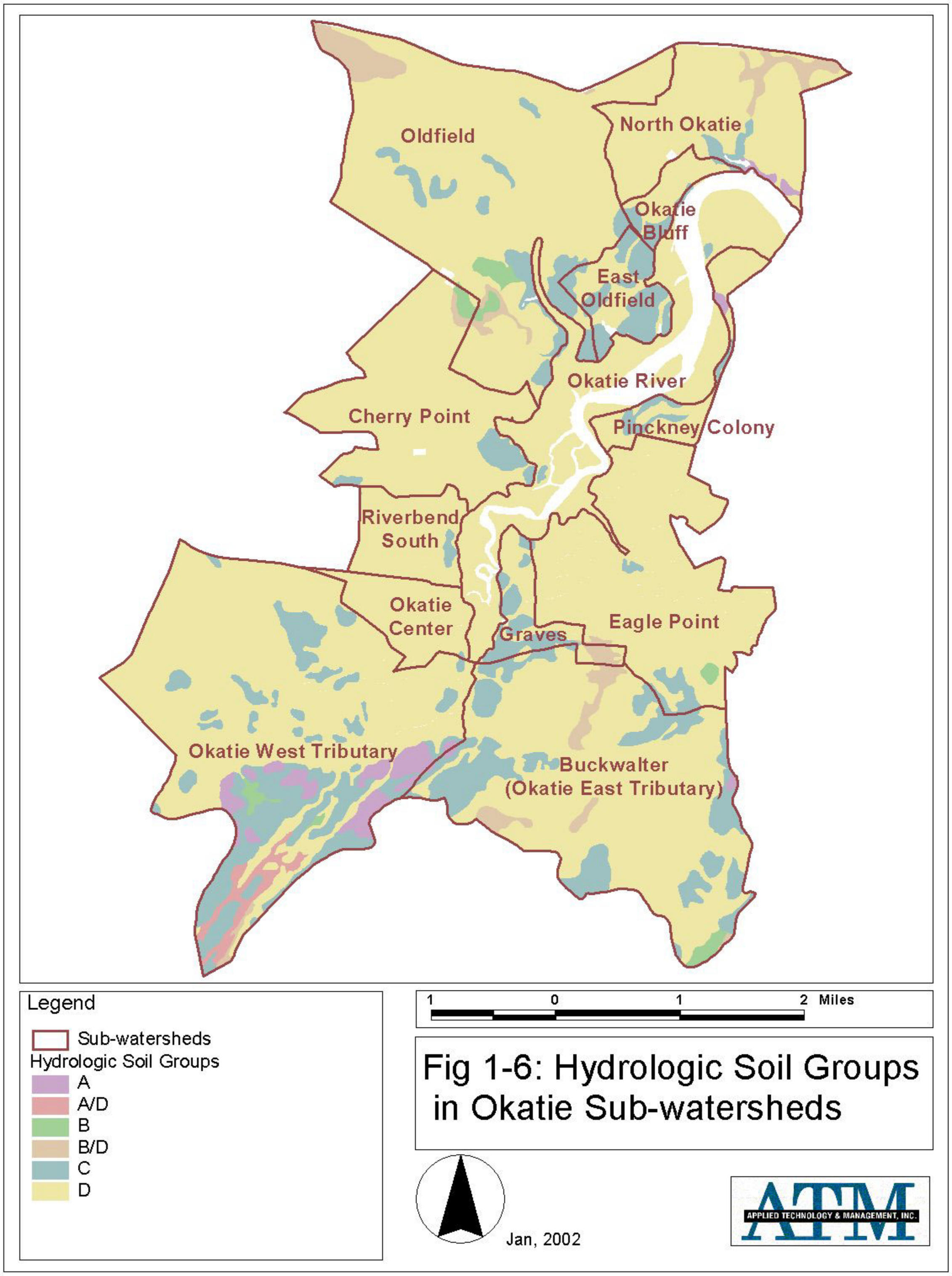


Fig 1-6: Hydrologic Soil Groups in Okatie Sub-watersheds

therefore, is typically reflective of Class D hydric soils. The soil has been classified as B/D and is equivalently modeled as a D soil.

1.4.6 Land Use

1.4.6.1 Present Land Use

Land use is one of the main factors that influence runoff as a percentage of rainfall. For example, if an area is paved rather than grassed, then a greater percentage of rainfall will become surface runoff. The PLU data are based on vegetation classification data compiled at the Beaufort County Geographic Information Services. Another source of information ATM used to determine land use was the USGS National Aerial Photography Program (NAPP) photographs of the study area (July 1994 and 1999 EROS Data Center, Sioux Falls, SD) with reference site verification.

The PLU spatial distribution is displayed on Figure 1-7. Table 1-3 presents the land use code table for the Okatie Watershed. The land use classifications were chosen based on their distinct runoff and pollutant load generating potential.

The PLU type acreages and percent of watershed area are presented in Table 1-4. The PLU summary indicates the majority of the land (55.1%) is classified as low impact water quality degradation range, composed primarily of forested silviculture operation. Low density residential comprises 17.5% of the area and 10.1% of the watershed is classified as wetlands. The pre-colonization composition of the land would have been primarily forested systems (~85%) and the wetlands may have been approximately 15% of the watershed.

Table 1-3 Land Use Classifications
Low Density Residential (LDR) = (0.2-4 residencies/acre)
Medium Density Residential (MDR) = (4.1-8 residencies/acre)
High Density Residential (HDR) = (8-20 residencies/acre)
Commercial (COM)
Agricultural (AG)
Rangeland (Range)
Water bodies (H2O)
Wetlands
Roads

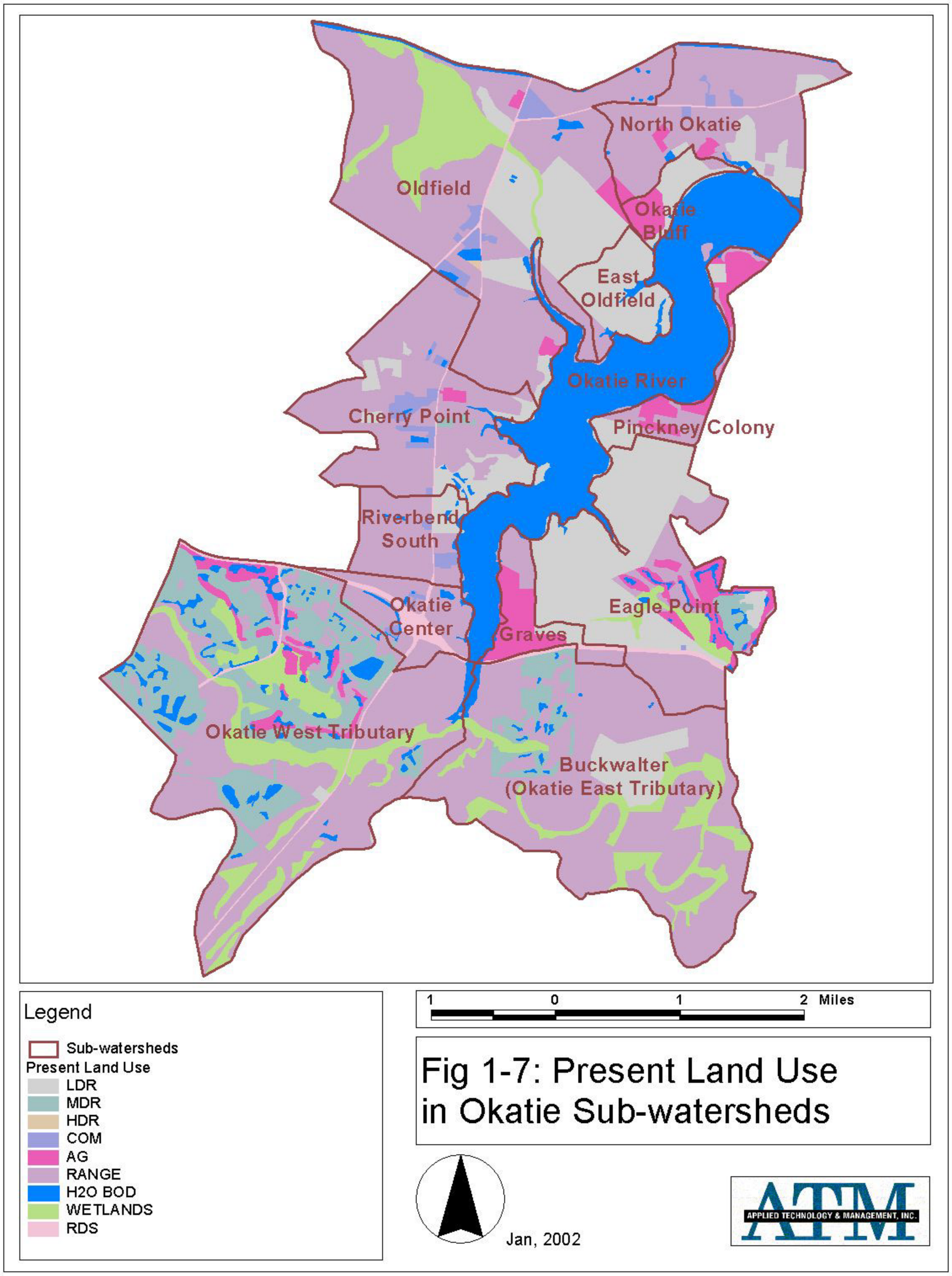


Fig 1-7: Present Land Use in Okatie Sub-watersheds

Table 1-4. PLU Watershed Summary		
LU Type	LU Acreage	% of Catchment Area
AG	711.87	5.16
COM	193.97	1.41
LDR	2415.81	17.52
MDR	1226.59	8.89
HDR	2.78	0.02
RANGE	7598.94	55.09
RDS	251.03	1.82
WETLANDS	1391.45	10.09
total land area	13792.45	acres

Table 1-5 FLU Watershed Summary		
LU Type	LU Acreage	% of Catchment Area
AG	711.865	5.16
COM	3032.41	21.99
LDR	594.07	4.31
MDR	5712.53	41.42
HDR	2.78	0.02
RANGE	2096.31	15.20
RDS	251.03	1.82
WETLANDS	1391.45	10.09
total land area	13792.45	acres

Source: SCDHEC, SCDNR, and NOAA, 2000.

For comparison, the following land use classifications are based on the SCDHEC (2000) study that incorporated areas inclusive of the Colleton River watershed; these may be used as a reference to the above-determined PLU ArcView GIS analysis. The Okatie River watershed area includes a fairly low percentage of impervious surfaces (15%) and transportation-related impervious area (2%) based on the tax map parcel data. The National Wetlands Inventory (NWI) updated in 1994 indicates 18.1% upland planted pine, 17.8% non-forested wetlands, 14.8% mixed upland forest, 11.3% forested wetland, 11.0% bay/estuary, 9.5% evergreen upland forest, and 9.1% cropland and pasture.

1.4.6.2 Future Land Use

Future land use (FLU) used the same classification system as PLU. The FLU spatial distribution is displayed on Figure 1-8. Table 1-5 gives the expected land use areas and percent of watershed. The planned FLU is based on zoning information obtained from Beaufort and Jasper Counties and the Lowcountry Council of Governments (LOWCOG) and reflects a built-out condition. This specific timeframe was not available from zoning. Future land use will increase medium residential home areas due to the planned development of the 6,000-acre Buckwalter tract and the completion of Woodbridge, Sun City, Grande Oaks, Okatie Center, Oldfield and Berkeley Hall PUDs. The major changes that will occur from PLU to FLU are the future level of MDR and COM property. MDR is expected to increase from 1226 acres (8.9%) to 5712 acres (41.4%) of the watershed, whereas commercial property is expected to increase from 194 acres (1.4%) to 3032 acres (22%). The rangeland, which includes silviculture, is expected to decrease from 7599 acres (55.1%) to 2096 acres (15.2%). These changes in land use are expected to impact runoff characteristics and water quality.

1.4.7 Structure/Stormwater Management Facilities

Existing structures and stormwater management facilities were inventoried by NRCS field surveys. The conditions of these structures were notated and/or photographed and flow directions noted. Additionally, information was gathered on the various stormwater structures from the PUD plans and SCDOT. Based on this inventory, structures in need of maintenance or repair include the following (see Figure 1-9):

- iw2d2 remnant Sun City construction road with undersized 6” polyvinyl chloride (PVC) pipe
- bw5ci (partially crushed culvert)
- 30’, 24” culvert (plugged)
- 20’, 24” CMP (culvert inlet crushed and filled to 12”)
- n77d2d (ditch blocked)
- n77d3d (ditch blocked)
- Northwestern-most extent of Hwy 170 ditch on the northwest side of bend is sediment filled from construction

1.4.8 Complaint Files and Noted Problem Areas

In discussions with the SCDOT, NRCS, Beaufort County Planning and Zoning Department, and the former Beaufort County Public Works Director (Chris Eversmann),

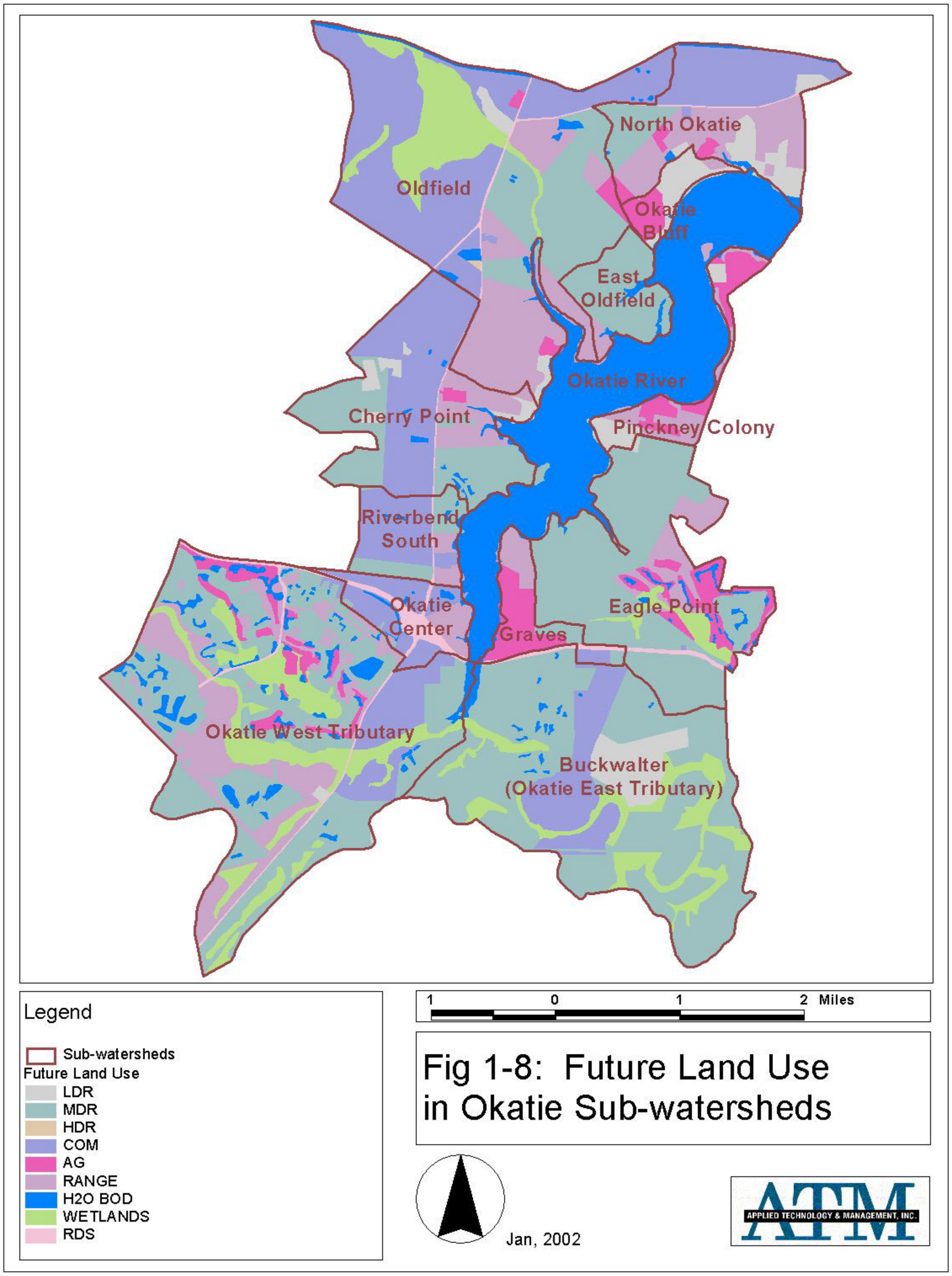


Fig 1-8: Future Land Use in Okatie Sub-watersheds

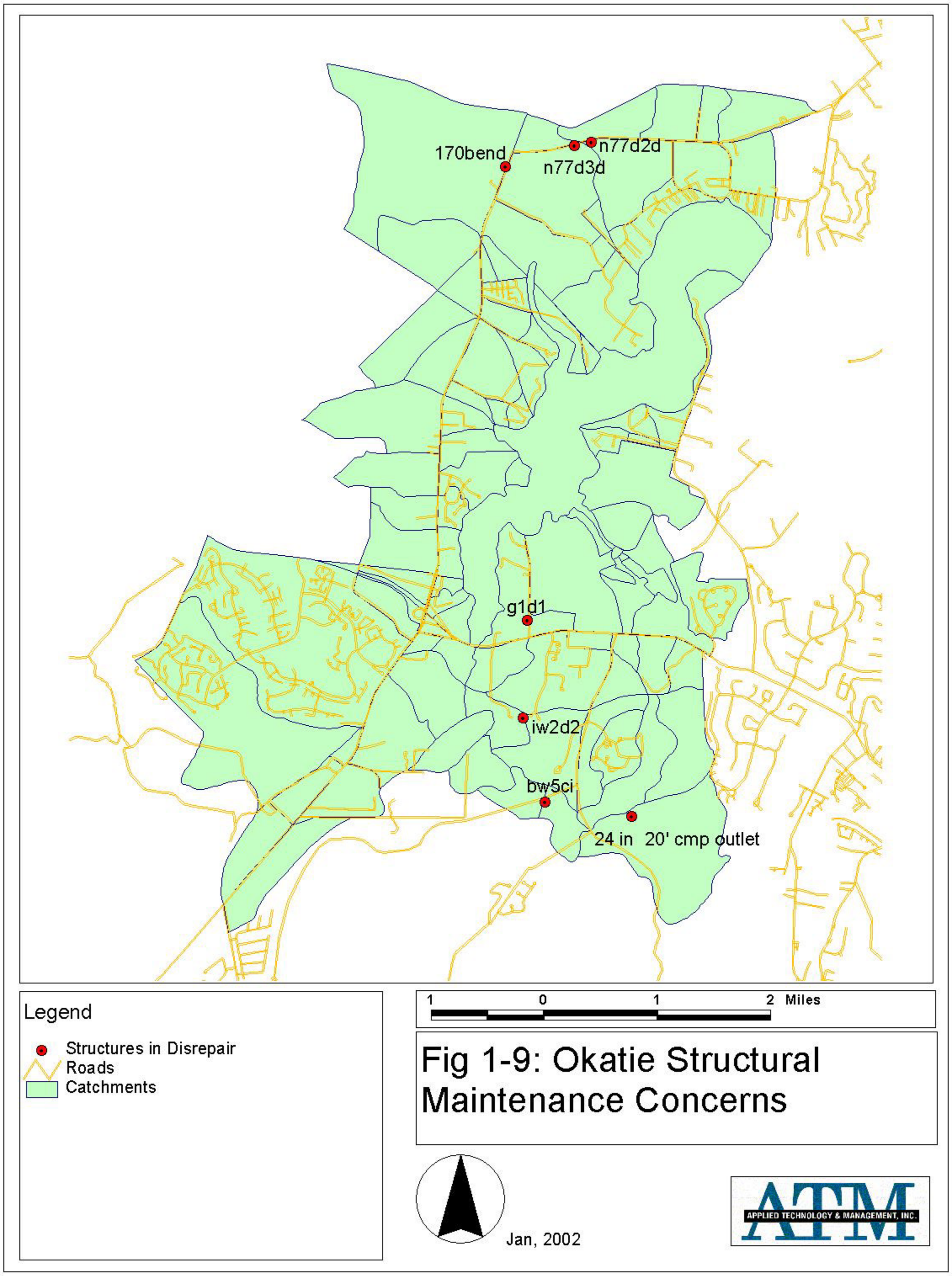


Fig 1-9: Okatie Structural Maintenance Concerns

it was indicated that there were no outstanding problem areas in the watershed. Additionally there were no subsequent complaint files. This may be attributed to the watershed having relatively new infrastructure that was designed to provide an LOS of no flooding resulting from a 25-year, 24-hour storm event.

The Beaufort County Stormwater Management Master Drainage Plan (May 1995) developed a work plan that proposed drainage improvements to the primary drainage system. A number of these proposed projects are located in the study area. The report did not provide a description of the nature of the drainage problem. A review of the pertinent projects in the Okatie watershed indicated that almost all of the projects are located in areas now developed, or currently being developed, as PUDs. It is assumed that any potential flooding problems in the area of the development would have been addressed in the PUD master stormwater management plan.

The plan also had a special projects summary that described localized flooding problems and proposed solutions. However, none of these projects are located in the Okatie Watershed. OCRM and EQC were also contacted in regard to citizen complaints. James Webster, P.E., said there are general complaints on the PUD developments Berkely Hall, Sun City, and Old Field about urban sprawl and potential water quality issues (pers. comm Webster, April 24, 2002, and Rocky Browder, Regional Permitting Manager).

1.4.9 Regulatory Framework

The state standard (SCDHEC, 2000) for FC bacteria in the Okatie River for the consumption of shellfish states that the most probable number (MPN) of FC geometric mean shall not exceed 14 colonies/100 ml, nor shall more than 10% of the samples exceed an MPN of 43 colonies/100 ml (SCDHEC, 2000). The standard is consistent with the National Shellfish Sanitation Program (NSSP) Model Ordinance and S.C. Regulation 61-47 used in establishing shellfish harvesting (Payne, 2001).

Development in Beaufort County is subject to county and state stormwater management regulations that address both peak flow attenuation and flood control and water quality treatment. State regulations require the attenuation of peak flows from the 2-year and 10-year, 24-hour design storm, and also require BMPs such as ponds for stormwater pollution control on new developments of 5 acres or more. The BMPs must provide a water quality storage volume specified in the state regulations. Beaufort County regulations require the attenuation of peak flows from the 25-year design storm, which is more conservative than state regulations. Best management practices required for stormwater quality treatment are regulated by the Beaufort County Manual for Stormwater BMPs (1998). In Jasper County, stormwater management is regulated by SCDHEC OCRM.

The following sections identify agencies that comprise the broad regulatory framework of the Okatie River Watershed Management Plan:

FEDERAL REGULATIONS:

<u>EPA/NOAA</u>

Federal regulations that directly affect stormwater runoff control include the NOAA Coastal Zone Management Act and the EPA National Pollutant Discharge Elimination System (NPDES). In the coastal counties of South Carolina, including Beaufort and Jasper Counties, these federal regulations are being implemented and managed by SCDHEC under the NPDES permitting program and the South Carolina Coastal Program SAMP from the Coastal Zone Management Act of 1972. The current SCDHEC strategy document for Municipal Separate Storm Sewer Systems (MSA) does not list any portion of Beaufort County as being required to submit a Notice of Intent (NOI) to be covered under the NPDES phase two jurisdiction and hence there are no current requirements, although there are no exemptions either. However, SCDHEC has informed Beaufort County and some of the municipalities that they will likely be added when the state of South Carolina finalizes the General Permit wording next year.

<u>United States Army Corps of Engineers (USACOE)</u>

The USACOE's involvement in stormwater control emanates from USACOE's regulation of dredge and fill (in waters of the United States) and any impacts to navigation in waters of the United States.

STATE REGULATIONS:

<u>SCDHEC</u>

Most land disturbing activities in South Carolina must comply with the Stormwater Management and Sediment Reduction Act of 1991. The final regulations, effective on June 26, 1992, establish the procedures and minimum standards for a statewide stormwater management program. For activities in the eight coastal counties, additional water quality requirements are imposed. All projects, regardless of size, that are located within one-half mile of a receiving water body in the coastal zone, must have wet detention ponds for water quality improvement. These ponds must have a permanent pool designed to store the first 0.5 inch of runoff from the entire site over a 24-hour period or store the first 1 inch of runoff from the built-upon portion of the property, whichever is greater. Storage may be accomplished through retention, detention, or infiltration systems, as appropriate for the specific site. In addition, for those projects that are located within 1000 feet of shellfish beds, the first 1.5 inches of runoff from the built-upon portion of the property must be retained on site. Since 1992, these regulations have been applied to the development of residential subdivisions, golf courses, and business areas (Payne, 2001).

The South Carolina Stormwater Management and Sediment Control Handbook for Land Disturbance Activities (SCDHEC, 1997) includes all existing South Carolina stormwater management regulations required for individuals to submit a stormwater management and sediment reduction permit application to SCDHEC. Elements of the state NPDES program, Coastal Zone Management Program, and state Stormwater Management and Sediment Regulation regulations are included in the Beaufort County BMP Manual (CDM, 1998).

The Coastal Zone Management Program for land development in Beaufort County is dependent on the size of land disturbance and degree of disturbance. For land disturbance under 2 acres either regulation R.72-307I or R.72-307H are applicable. Depending on the type of development outlined, R.72-307I is the more stringent of the two. All projects over 2 acres are held under either R.72-307I or R.72-305, R.72-307, and SCR100000 for projects over 5 acres. These more stringent regulations require: plan approval by implementing agency, plan preparation by a registered Professional Engineer (P.E.) /Landscape Architect/Land Surveyor, BMPs to control erosion and sediment/measures to control stormwater quality and quantity.

The Coastal Zone Management Program stormwater quality BMP requirements include the Wet Detention Pond System, Extended Dry Detention Pond and Infiltration practices. These must be designed with higher stringency depending if they are within 0.5 mile of a receiving water body in a coastal zone and even more stringent if they are within 1,000 feet of shellfish beds. The requirement for infiltration facilities within 1,000 feet of shellfish beds requires 1.5 inches per impervious acre of drainage, which is 50% greater than the general requirement.

NPDES stormwater discharge permit requirements for industrial development are summarized in Stormwater Permitting in South Carolina (SCDHEC, July 2000) (Water Quality Permits R.61-69). Also the general permit SC100000 requires a stormwater pollution plan that includes BMPs, good housekeeping practices, spill prevention procedures, and employee training. Monitoring may also be required for certain industrial activities. Typically, the requirements of the NPDES general permit overlap with the requirements of the Stormwater Management and Sediment Reduction Act of 1991, such that the plans and specifications developed for SCDHEC review are sufficient to satisfy the NPDES general permit requirements.

COUNTY REGULATIONS

Design criteria for stormwater management facilities are located in Section 5.4.3 of the Zoning and Development Standards Ordinance for Beaufort County. Topics addressed in Section 5.4.3 of the ordinance include: design storms, general quantity and quality requirements, retention-detention facility selection and design, open drainage system requirements, hydraulic design criteria, and plan requirements. County design criteria require that the pond be designed so that the post-development peak flow rate is less than or equal to the pre-development flow rate for the 25-year 24-hr design storm, which is more stringent then the state requirement. Additionally, there are requirements on other BMPs such as filter mediums, swales and infiltration ditches. Beaufort County requires the design of stormwater BMPs so that discharges from new developments will meet an anti-degradation standard as described in the Beaufort County Manual of Stormwater BMPs

1.4.10 LOS – Flood Protection and Receiving Water Protection

The LOS for recent and new development is determined by regulations in Beaufort County by the Beaufort County and state (SCDHEC) regulations. Eagle Point and Oldfield stormwater collection facilities were designed to have “zero degradation” on water quality. This was done by development of a BMP plan in which estimated pollutant loads from the development would be reduced to their pre-development levels. All new developments are to be designed under the criteria and BMPs listed in the Beaufort County Manual for Stormwater BMPs (1998).

State standards in Jasper County are based on SCDHEC requirements and are variable for size and location of development, the type of BMP used and distance from receiving waters. Typically, the state regulations for Jasper County in the Okatie watershed are designed to have a permanent pool volume equivalent to 0.5 inch of runoff per acre of drainage, as well as another 0.5 inch of storage above the permanent pool. The storage above the permanent pool is required to bleed down over a 24-hour period. The state treatment requirements are typically less restrictive than Beaufort County regulations.

2.0 METHODOLOGIES

2.1 Watershed and Catchment Delineations

The Okatie River watershed is characterized by flat slopes. As such, many factors other than topography, such as roads, can determine where catchment boundaries are placed. Catchment area delineations were identified from the following:

- USGS quadrangle maps with contours;
- Beaufort County Master Drainage Plan, May 1995;
- Buckwalter Tract Drainage Study, July 2000;
- Available PUD drainage maps;
- 1999 orthophoto obtained from the GIS at SCDHEC data server available data layers;
- Survey data and field confirmation by NRCS

Generally, a cursory development of both the watershed and catchment boundaries was completed using the USGS quadrangle maps, the drainage study in the Stormwater Management Master Drainage Plan for Beaufort County, and aerial photogrammetric maps. Field survey of the watershed, its primary channel structures and cross-sections, and observed flow directions served to refine the sub-catchment boundaries. Field investigations were then used on the tributary channels to further define sub-catchment boundaries. Figure 2-1 shows observed flow directions in relation to watershed features encountered in the field survey.

Figure 2-2 shows the major sub-watershed delineations associated with the Okatie River and its major tributaries. Figure 2-3 shows the catchment boundaries with their associated number designations and their hydrologic connectivity. Figure 2-4 presents the catchment boundaries located within the major sub-watersheds. The following paragraphs briefly discuss the twelve sub-watersheds.

Fig 2-1: 1999 Aerial Photo with Runoff Flow Paths

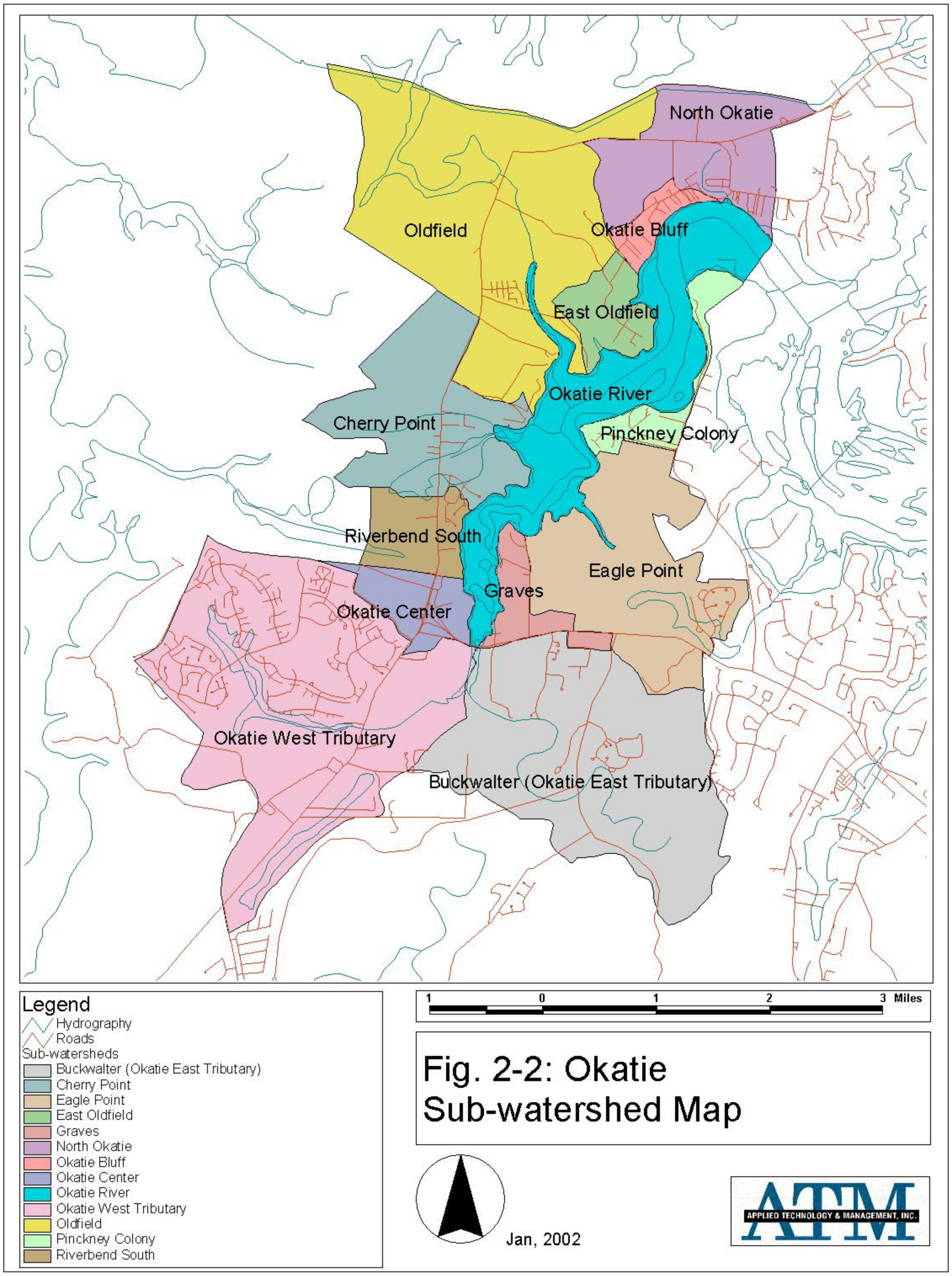


Fig. 2-2: Okatie Sub-watershed Map

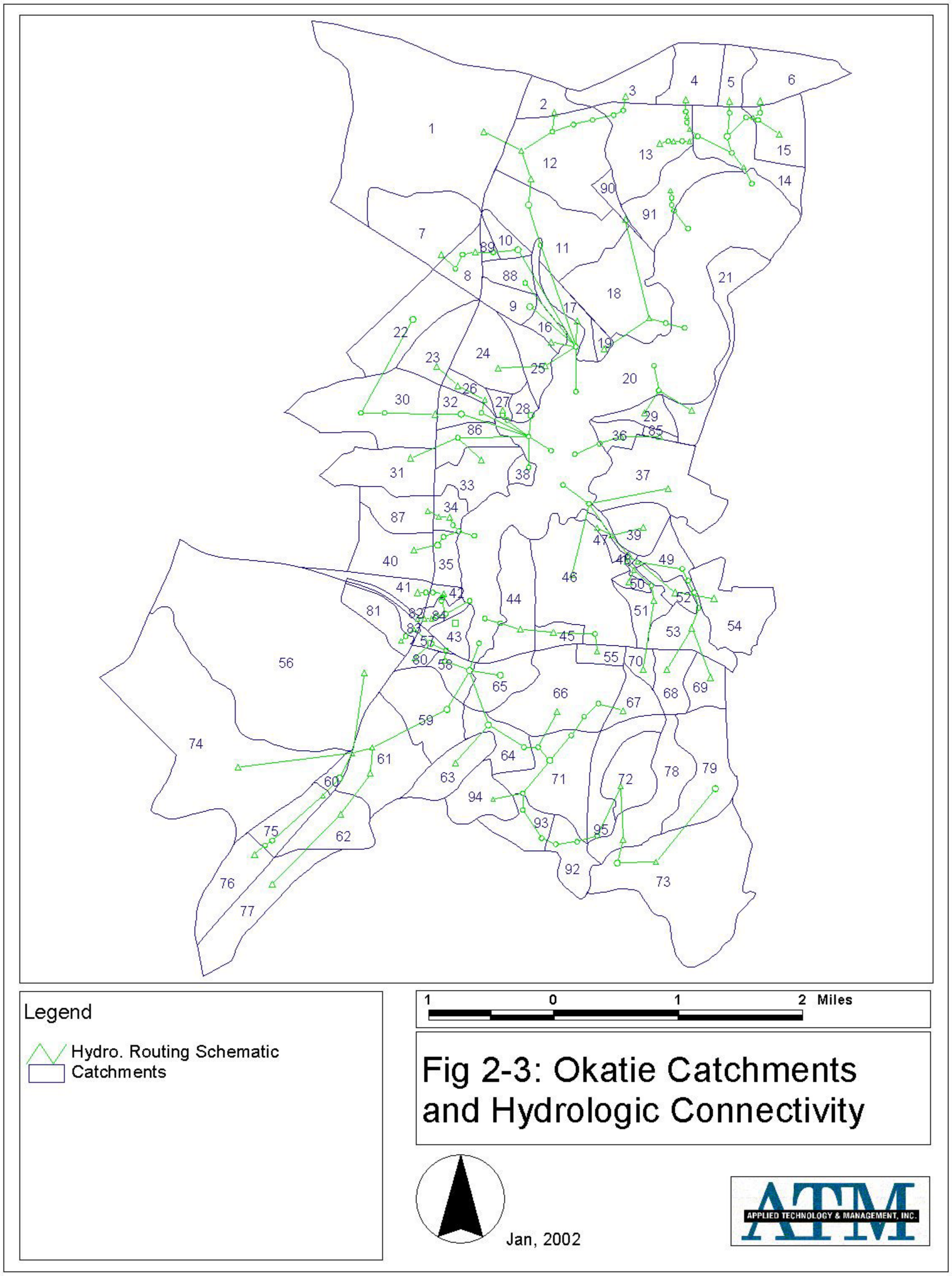


Fig 2-3: Okatie Catchments and Hydrologic Connectivity

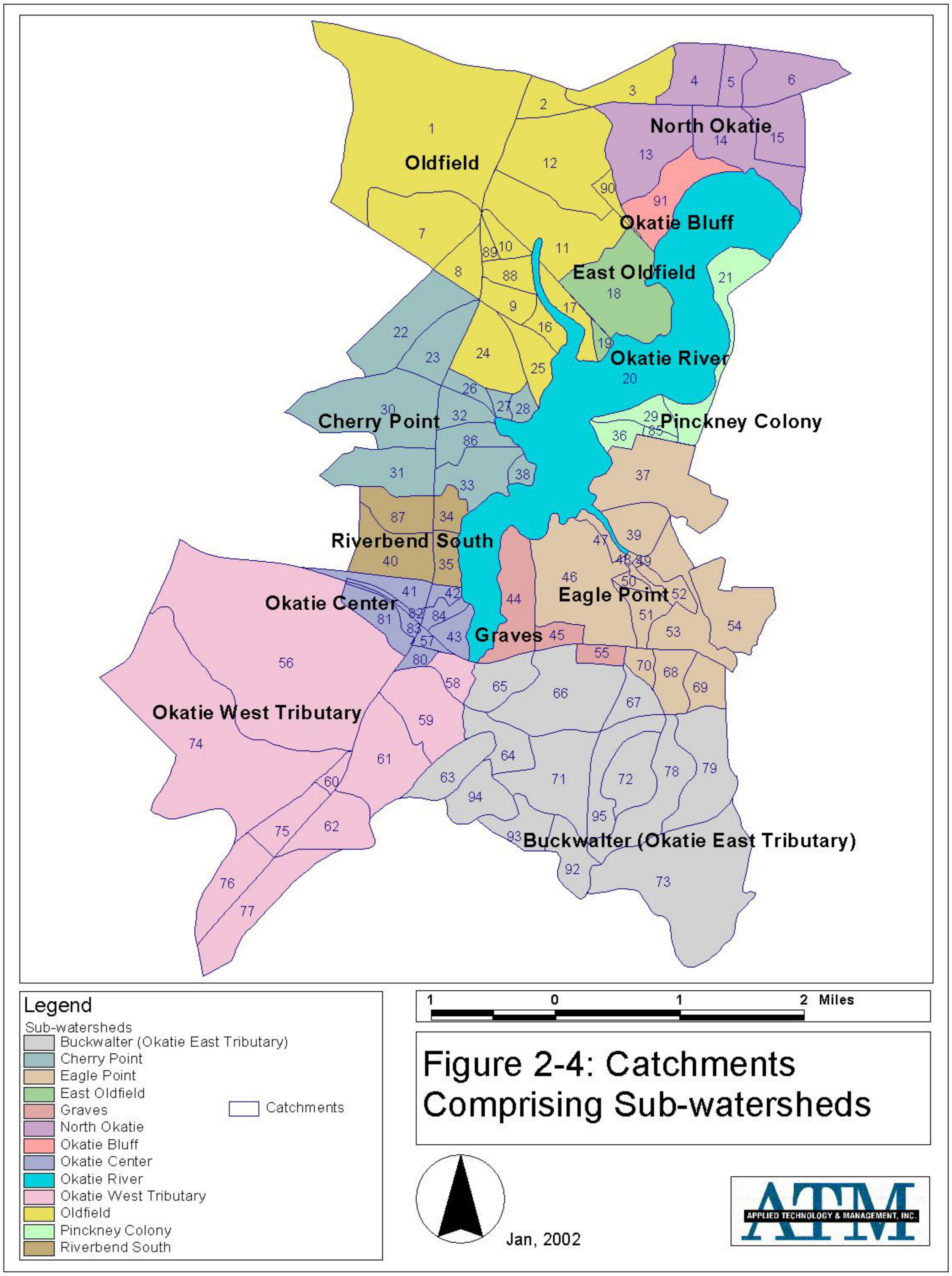


Figure 2-4: Catchments Comprising Sub-watersheds

2.1.1 Okatie East Tributary

This sub-watershed is located in the southeast portion of the Okatie watershed (see Figure 2-2) and has a total of 2,520 acres. Seventy-seven percent of the soils are classified as Class D and twenty-two percent is classified as Class C. The PLU is primarily composed of 69.9% Range (silviculture and forest), 14% wetlands, 7.4% LDR and 7.0% MDR. Future development, as provided by Beaufort County zoning, is planned to change the landscape by primarily shifting Range (0.0%) to MDR (62.9%) and COM (14.0%). For details, see Appendix 2.

2.1.2 Oldfield

This sub-watershed is located in the northwest portion of the Okatie watershed (see Figure 2-2) and has a total of 2,794 acres. Eighty-nine percent of the soils are classified as Class D and eight percent are Class C soils. The PLU is primarily composed of 57.6% Range (silviculture and forest), 18% LDR, 16.7% wetlands, and COM, 2.6%. Future development is planned to change the landscape by primarily shifting Range to COM (39.6%) and MDR (19.4%). For details, see Appendix 2.

2.1.3 North Okatie

This sub-watershed is located in the northeast portion of the Okatie watershed (see Figure 2-2) and has a total of 952 acres. Ninety-three percent of the soils are classified as Class D and four percent are Class C soils. The PLU is primarily composed of 77.5% Range (silviculture and forest), 12.8% LDR, and COM 2.0%. Future development is planned to change the landscape by primarily shifting Range to COM (34.6%) and MDR (12.0%). For details, see Appendix 2.

2.1.4 Okatie Bluff

This 161-acre sub-watershed is located in the northeast portion of the Okatie watershed just south of the North Okatie sub-watershed (see Figure 2-2). Seventy-four percent of the soils are classified as Class D and twenty-six percent are Class C soils. This sub-watershed is not expected to change land use because it is nearly built out. The PLU and FLU are primarily composed of 54.5% LDR, 37.7% AG. For details, see Appendix 2.

2.1.5 East Old Field

This sub-watershed is located in the northeast portion of the Okatie watershed (see Figure 2-2) and has a total of 328 acres. Thirty-nine percent of the soils are classified as Class D and fifty-nine percent are Class C soils. The PLU is primarily composed of 87%

LDR, and Range 7.2%. Future development is planned to change the landscape by primarily shifting LDR to MDR (87.0%). For details, see Appendix 2.

2.1.6 Cherry Point

This sub-watershed is located in the eastern portion of the Okatie watershed just south of Oldfield sub-watershed (see Figure 2-2) and has a total of 1258 acres. Ninety-one percent of the soils are classified as Class D and six percent are Class C soils. The PLU is primarily composed of 77.3% Range (silviculture and forest), 14.1% LDR, and COM 5.5%. Future development is planned to change the landscape by primarily shifting Range (12.9%) to COM (43.0%) and MDR (34.8%). For details, see Appendix 2.

2.1.7 River Bend South

This sub-watershed is located in the eastern portion of the Okatie watershed just south of Cherry Point sub-watershed (see Figure 2-2) and has a total of 374 acres. Ninety-six percent of the soils are classified as Class D and four percent are Class C soils. The PLU is primarily composed of 78.4% Range (silviculture and forest), 13.0% LDR, and COM (5.3%). Future development is planned to change the landscape by primarily shifting Range (10.0%) to COM (59.4%) and MDR (27.2%). For details, see Appendix 2.

2.1.8 Okatie Center

This sub-watershed is located in the southeast portion of the Okatie watershed just south of Riverbend South sub-watershed (see Figure 2-2) and has a total of 346 acres. Ninety-nine percent of the soils are classified as Class D. The PLU is primarily composed of 70.4% Range (silviculture and forest), 19.6% roads, and COM (5.3%). Future development is planned to change the landscape by primarily shifting Range (10.0%) to COM (59.4%) and MDR (27.2%). For details, see Appendix 2.

2.1.9 Okatie West Tributary

This sub-watershed is located in the southwest portion of the Okatie watershed (see Figure 2-2) and has a total of 3,284 acres. Sixty-nine percent of the soils are classified as Class D, twenty percent are classified as Class C, and six percent of the land is Class A. The PLU is primarily composed of 43% Range (silviculture and forest), 29.7% MDR, and wetlands (15.1%). Future development is planned to change the landscape by primarily shifting Range (19.8%) to COM (8.0%) and MDR (44.9%). For details, see Appendix 2.

2.1.10 Pinckney Colony

This sub-watershed is located in the east portion of the Okatie watershed just north of the Eagle Point sub-watershed (see Figure 2-2) and has a total of 279 acres. Eighty percent of the soils are classified as Class D and seventeen percent are classified as Class C. The PLU is primarily composed of 34% Range (silviculture and forest), 42.7% AG, and LDR (21.1%). Future development is not planned in this sub-watershed. For details, see Appendix 2.

2.1.11 Eagle Point

This sub-watershed is located in the southeast portion of the Okatie watershed (see Figure 2-2) and has a total of 1,532 acres. Ninety-five percent of the soils are classified as Class D and four percent are classified as Class C. The PLU is primarily composed of 56.5% LDR, 22.3% Range (silviculture and forest), and 9.7% AG. Future development is planned to change the landscape by primarily shifting Range (10.5%) and LDR (.3%) to MDR (71.5%). For details, see Appendix 2.

2.1.12 Graves

This sub-watershed is located in the southeast portion of the Okatie watershed just west of Eagle Point (see Figure 2-2) and has a total of 268 acres. Fifty-two percent of the soils are classified as Class D and thirty-nine percent are classified as Class C. The PLU is primarily composed of 50.0% AG, 32.0% Range (silviculture and forest), and 11.0% LDR. Future development is planned to change the landscape by primarily shifting Range (21.0%) to MDR (14.8%) and COM (7.6%). For details, see Appendix 2.

2.2 Water Quantity Evaluations

2.2.1 Model Selection

The XP-SWMM model was selected to perform water quantity simulations for this study. XP-SWMM is a mathematical model that simulates the hydrologic and hydraulic response of watersheds and drainage systems. XP-SWMM is a link-node model that performs hydrology, hydraulics and quality analysis of storm water and wastewater drainage systems including sewage treatment plants, and water quality control devices (BMPs). It uses real storm events data and system characteristics (catchment, conveyance, storage/treatment) to predict runoff and its routing throughout the drainage system, as well as water quality of the runoff. All aspects of the urban hydrologic and quality cycles are simulated, including surface and subsurface runoff, transport through the drainage network, storage and treatment. The model provides for both time series output and concentration versus time (hydrographs, pollutographs) as well as continuous simulation where the objective is to determine the cumulative effects of a storm event, such as total pounds of pollutants discharged.

XP-SWMM is composed of a number of "blocks" or program modules of which the following are especially germane to the present project.

- **RUNOFF Block** This "block" generates surface and subsurface runoff based on rainfall hyetographs, antecedent conditions, land use, soil characteristics and topography. There are 9 methods available for surface runoff generation, including the SCS unit hydrograph method, which was chosen for use in this study. This method uses the time of concentration (Tc), SCS curve number (CN), duration of the storm and a Shape Factor to generate hydrographs. Any shape factor ranging from 25 to 950 may be used with either a curvilinear or triangular unit hydrograph. The initial abstraction is based either on a depth or a fraction of the storage based on the CN. User defined rainfall data allow the modeler to use data from data loggers for long periods of records. Continuous simulation uses 45 to 55 years of measured hourly or 15 minute precipitation.

- **EXTRAN Block** EXTRAN is a hydraulic flow routing model for open channel or closed conduit systems. This "block" receives as input the hydrograph results generated from the RUNOFF block. EXTRAN is applicable to systems where the assumption of steady flow, for purposes of computing backwater profiles, cannot be made. As a general rule, the upstream portions of the drainage system are represented in RUNOFF block. The dividing line for the two systems is the point where backwater effects, surcharge, and/or diversion facilities affect the flow and head computation. Pipes and channels downstream of this point are generally included in EXTRAN. EXTRAN then performs dynamic routing of stormwater flows throughout the major sections of the storm drainage system. The program simulates branched networks, backwater due to tidal effects, and flow transfer by weirs, orifices, and storage. The outputs from the model are water surface elevations and discharge at selected system locations. Due to the flat topography and the aerial extent of the tidal influence, EXTRAN was used exclusively for the dynamic routing of stormwater flows in the Okatie River watershed.

2.2.2 SCS Unit Hydrograph Methodology

The Unit Hydrograph methodology utilized by the SCS was chosen for use in this study. Generally, this methodology calls for the use of a "Unit Hydrograph" to determine the rainfall/runoff relationships. The unit hydrograph is an idealized runoff hydrograph (a plot of runoff rate versus time). This hydrograph is formulated so that the volume of runoff under this theoretical hydrograph is one unit, thus the Unit Hydrograph. The relative rate on the unit hydrograph is adjusted to account for the total volume of rainfall that occurs with an actual hydrograph produced. This hydrograph provides the rate of flow at a specific time and the total incremental volume of runoff for the storm.

Input to the unit hydrograph compilations include: total rainfall volume, duration of storm, desired rainfall distribution, peak rate factor, area of the watershed, CN, initial abstraction, Tc, and simulation time step.

2.2.1 Model Network

The model network was developed based on catchment delineations and flow patterns observed during structure inventory and survey activities. The flow patterns observed during the field survey are presented on Figure 2-1. The resultant model network is presented on Figure 2-3.

2.2.2 Calibration Technique

Because stage and flow data do not exist for locations within the watershed, calibration of the model was performed by review of available PUD engineering reports and the modeling results contained therein. Adjustments to basin storage, where justified by available data, CNs, and Tc values were made to approximate model results contain within the PUD reports. The PUD reports evaluated their associated internal water management system in greater detail than what was suitable for the Okatie River watershed model. The goal was to approximate the hydrologic and hydraulic contributions of the individual PUDs so that their effect on the overall primary conveyance systems could be evaluated.

2.3 Hydrologic Parameters

This subsection presents the methodology for developing the hydrologic parameters in the water quantity evaluations for this study. A summary of the PLU and FLU or built-out condition hydrologic parameters, and the HSG classification for each sub-watershed is presented in Appendix 2.

2.3.1 Runoff Curve Numbers

The CN for the various catchments was determined utilizing information on the land use (Figures 1-7 and 1-8) and soil classifications (Figures 1-4 through 1-6) within the area contained in the project GIS. The soil classifications are based on the SCS Soil Survey for Beaufort and Jasper Counties. The CN numbers were developed utilizing the guidelines established in NRCS TR-55.

2.3.2 Times of Concentration

The Tc is used to denote the travel time of runoff from an area. Generally, this is said to be the time it takes a drop of water to flow from the farthest distance in the watershed to the watershed's outfall. The Tc for the various catchments was calculated using NRCS TR-55.

2.3.3 Peak Rate Factors

The peak rate factor is a parameter used to reflect the effect of watershed storage on runoff hydrograph shape. The selection of the peak rate factor is dependent primarily on the watershed slope. The flatter the watershed slopes, the lower the peak rate factor. NRCS recommends that for watersheds with very mild slopes (0.5%), a peak rate factor of 256 be used. While there are some slopes in the Okatie River watershed near tributary streams which are greater than 0.5%, the land slope is predominately 0.5% or less. Therefore, a peak rate factor of 256 was chosen for this study.

2.4 Hydraulic Parameters

2.4.1 Stage-Area Data

Stage-area information was developed by digitizing topographic contours for major depression areas within a catchment. The data were used to either refine catchment depression storage estimates or used in the hydraulic routings. The volume of storage is internally calculated by the stormwater models by use of the trapezoidal method (volume is equal to the average of the area times the depth). Data sources for these curves included USGS quad maps and PUD drainage master plans and 1-foot contour topographic maps.

2.4.2 Structures/Facilities

Hydraulic data for culverts, storm sewers, control structures, and watercourse cross-sections were obtained from the present stormwater facility inventory, as supplied by NRCS, PUD stormwater master plans, the Buckwalter Tract Drainage Study, and field reconnaissance. These data included elevations, lengths, geometries, surface roughness, local loss characteristics, and other pertinent features. The facility locations, sizes, and lengths were entered into a GIS database.

2.4.3 Boundary Conditions

Stage-time or discharge-time data were necessary to use as boundary conditions for the hydraulic simulations. The limit of the Okatie watershed was determined to be at the confluence of the Okatie and the Colleton Rivers. It was decided that the appropriate boundary condition for the water quantity simulations would be a representative tidal cycle for the area. Tidal information representative of a spring tide was gathered from the Tides and Currents for Windows^{TM}. The data were then converted to subsequent elevations using the NOAA benchmark database. These elevations were input into the XP-SWMM model, tide coefficients were computed and a tide curve was developed. The timing of the high tide was set to approximately coincide with the peak of the generated runoff hydrograph to provide a typical worst case flooding condition similar to what might be encountered during a tropical storm.

3.0 WATER QUANTITY EVALUATIONS

A stormwater quantity model was applied to the watershed and its primary conveyance systems in order to identify system-flooding problems and to assess the LOS provided with respect to drainage and flooding. Because stage and flow data do not exist for locations within the watershed, calibration of the model was performed by review of available PUD engineering reports and the modeling results contained therein. Adjustments to basin storage, where justified by available data, CNs, and Tc values were made to approximate model results contained within the PUD reports. The PUD reports evaluated their associated internal water management system in greater detail than what was suitable for the Okatie River watershed model. The goal was to approximate the hydrologic and hydraulic contributions of the individual PUDs so that their effect on the overall primary conveyance systems could be evaluated.

The watershed model actually consists of models for each of the 13 independent sub-watershed systems. Simulations were performed for each system for the 2-, 5-, 10-, 25-, and 100-year 24-hour storm events under both PLU and FLU scenarios.

3.1 Present Conditions

This section provides results from the stormwater model simulations for the PLU and existing hydraulic conditions. Locations of water quantity problem areas determined from the model simulations are shown on Figure 3-1.

Results from the simulations indicate that a high level of service for flood protection is currently being provided by the primary conveyance system. All major evacuation routes (State Road 170 and U.S. Highway 278) are passable for the 25-year, 24-hour storm event. The high level of flood protection is not surprising given the following conditions. First, the majority of the development within the watershed is new (since 1994) and was designed meet state and county requirements to provide peak flow attenuation and flood protection for storm events up to the 25-year, 24-hour storm event. A high level of service for flood protection is required as part of the stormwater management permitting process. Second, most of the primary conveyances are relatively short with broad tidal creeks at their outfall, providing minimal flow restriction.

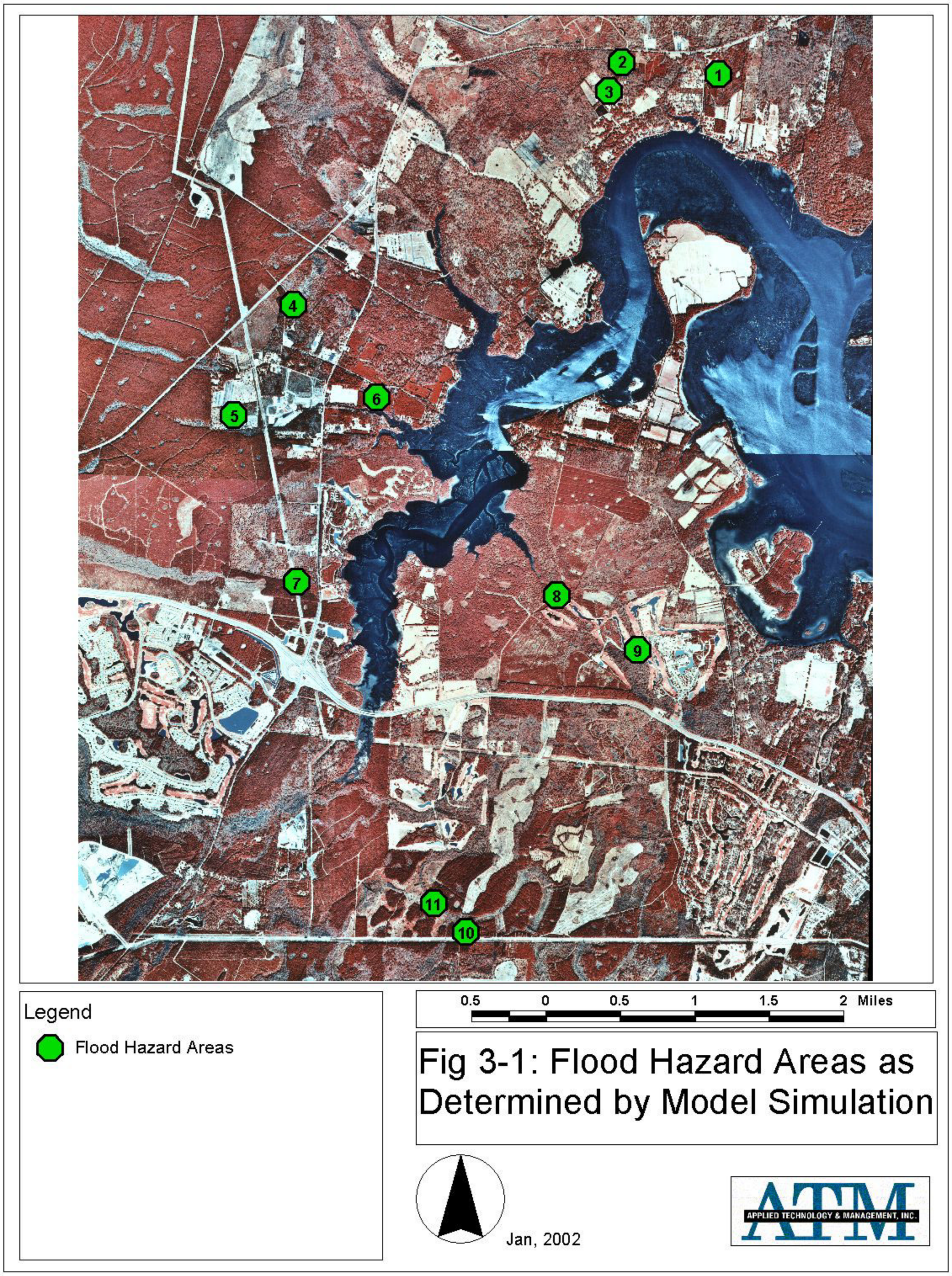


Fig 3-1: Flood Hazard Areas as Determined by Model Simulation

Since 1994, the area has experienced a number of large storm events that correspond to long return period, design type events. They include the following:

Beaufort Wastewater Treatment Plant (BWWTP):	
October 2 and 3, 1994	7.65 inches (25-year storm)
July 9, 1996	6.83 inches (10-year storm)
February 17, 1998	5.1 inches (5-year storm)
Hilton Head:	
October 2 and 3, 1994	11.2 inches (>100-year storm)

Discussions with Beaufort County staff indicated no major flooding problems were reported for these events. This is probably due to the low density of development existing at that time. Development since these events occurred has been done in a way that provides for a high level of flood protection.

The areas of flooding shown on Figure 3-1 are typically in areas with low-density, or no development, and occur in relatively low topographic areas. Each area is discussed below.

3.1.1 North Okatie

Problem Area 1. This area is a relatively low area bounded by Old Bailey's Road and State Road 170. Simulations indicate significant ponding for the 5-year, 24-hour storm event and greater. It does not appear to threaten any homes or roads. Old Bailey's Road remains clear for the 25-year, 24-hour storm event.

Problem Area 2. A driveway off Camp St. Mary's Road is barely overtopped (approximately 1 inch) for the 25-year, 24-hour storm event but remains passable. Camp St. Mary's Road does not appear to be adversely affected.

Problem Area 3. This is a relatively low topographic area behind a sparsely developed area located north of Okatie Bluff Road and west of Camp St. Mary's Road. The area is characterized by three access roads with flooding occurring at the road crossings. Flooding occurs for 5-year and greater, 24-hour storm events. There are a few agricultural buildings in the area which do not appear to be threatened.

3.1.2 Cherry Point

Problem Area 4. This area is located in an undeveloped area between John Smith Road and State Road 170. Significant flooding occurs for the 10-year, 24-hour storm event. No buildings or roads are threatened.

Problem Area 5. This area is located east of John Smith Road along the power line easement. Flooding is occurring along the power line easement road on one of the major conveyance ways in the Cherry Point sub-watershed for the 25-year, 24-hour storm event. This is a low area with no primary or secondary roads or buildings in the area.

Problem Area 6. A private road is overtopped for the 5-year, 24-hour storm event at the 36-inch reinforced concrete pipe (RCP) crossing. The residence itself does not appear to be threatened.

3.1.3 River Bend

Problem Area 7. Some minimal flooding and road overtopping (approximately 3-4 inches) occurs for the 25-year, 24-hour storm event at the 18-inch RCP crossing of State Road 170 just south of the River Bend PUD. The flooding occurs west of State Road 170 in an undeveloped area with a large slough. No buildings are threatened by flood waters. The flooding here may be conservative in that insufficient storage may have been used in the simulations. There was not sufficient data to justify increasing available catchment storage

3.1.4 Eagle Point/Berkley Hall

Problem Area 8. This area is located at two 84-inch corrugated metal pipes (CMPs) crossing what is now an unimproved road and is at the confluence of two major flow ways. The road is overtopped for the 5-year, 24-hour storm event. Per discussions with the former property owner, these culverts were washed out during the October 1994 storm event. This area will be improved as part of the development of the Berkley Hall PUD.

Problem Area 9. This area is located in a large wetland slough in the Eagle Point development. Flooding occurs due to a narrowing of the wetland at the Eagle Point golf course for the 25-year storm event. Only portions of the golf course are affected with no structural damage apparent.

3.1.5 Okatie East Tributary (Buckwalter Area)

Problem Area 10. This area is located at a culvert crossing of a silvicultural road which is overtopped for all storm events. Per the Buckwalter Tract Drainage Study, this crossing is scheduled for improvements as part of the future development activities of the tract. This should alleviate this problem.

Problem Area 11. This area is located in the large slough that is south of the Island West PUD. Significant ponding begins to occur for the 10-year, 24-hour storm event. The area is currently in silviculture and no roads or buildings are affected. The cause of the flooding is likely due to the presence of a construction road traversed with a 6-inch PVC pipe at the Island West PUD. Per the Buckwalter Tract Drainage Study, this structure is also scheduled for removal as part of future development activities on the tract. Removal of the road will restore the natural conveyance properties of the tributary.

3.2 Future Conditions

To determine the adequacy of the existing stormwater management system for future development conditions, simulations were performed using FLU and the existing hydraulic condition of the stormwater management system. The FLU, reflective of a built-out condition, shows a development trend of MDR and COM development contained within PUDs throughout the watershed, particularly in Jasper County along State Road 170.

The pattern of development planned for the Okatie River Watershed is not expected to dramatically impact the existing stormwater management system. Developments must be designed to provide peak flow attenuation and flood protection for the 2- and 10-year, 24-hour storm events as per state standards. Beaufort County has the additional requirement of peak flow attenuation and flood protection for the 25-year, 24-hour storm event. Therefore, resultant increases in runoff volumes and rates due to development are not expected to be significant. This would be more likely if Jasper County had the same requirements for new developments as Beaufort County.

4.0 WATER QUALITY EVALUATIONS

4.1 Water Quality Review

The implementation of the Clean Water Act of 1972 and subsequent amendments have had a significant effect on reducing the discharge of point source contaminants. Clean Water Act, Chapter 26, "Water Pollution Prevention and Control," Title 33 U.S.C. §§ 1251-1387. However, long-term (chronic) exposure to lower levels of contaminants in the estuarine environment may affect disease resistance, feeding ecology, reproductive output, and community relationships of aquatic fauna and flora (SCDNR and NOAA, 1996). The leading pollutants or stressors to estuaries are nutrients (eutrophication) and secondly bacteria (i.e., FC) (EPA, 2000). Because of the history of local shellfish bed closures, FC bacteria has been identified as a major concern in the Okatie River. This report focuses on addressing FC issues and additionally summarizes other problematic contaminants.

Non-point source (NPS) inputs are more difficult to control. Urban runoff NPSs include water draining from streets, service stations, and residential areas and typically contains metals, and organic and inorganic compounds toxic to marine life. Residue from automobile exhaust, tire particles on highways, and leached materials from solid waste disposal sites are a few urban NPSs of water pollution. For example, the 1996 EPA report to Congress found that urban runoff/storm sewers were a source of pollution for 45 percent of impaired estuaries (second only to industrial discharges (EPA, 2000). Stormwater runoff additionally impacts water quality by transporting FC bacteria to shellfish growing areas (Payne, 2001).

In less urbanized areas, NPS pollution is generally the primary threat to water quality. In those areas, NPS includes runoff from silviculture and agricultural fields (nutrients, pesticides, and sediments) and livestock operations (nutrients, bacteria, and sediments). Inputs of NPS pollutants (urban and rural) to coastal waterways are heaviest during precipitation events and, therefore, are more difficult to monitor and document (SCDNR et al., 1996).

Shellfish in poor quality waters may bio-accumulate contaminants as they feed. Eastern oysters, *Crassostrea virginica,* may filter feed up to 30 gallons per day of water and thus may concentrate pollutants from their food particles in large amounts. Additionally clams and mussels (primarily hard clams *Mercenaria mercenaria* and un-commercially harvested *Geukensia demissa* and *Brachidontes exustes*) also occur in area waters. Clams and mussels bioaccumulate contaminants in the same manner as oysters. The main pollutants of concern are the enteric pathogens including bacteria, viruses, protozoa, and helminthes. Heavy metals, hydrocarbons, sediments and other contaminants are also of concern.

Additionally, salinity (and subsequent freshwater hydrologic inputs) affects the life cycle and survivability of the eastern oyster. The optimal salinity range is between 10 to 20 parts per trillion (ppt) for the adult oyster and 10 to 30 ppt for spawning and larval stages of the oyster. Adults can live in salinity between 2 and 40 ppt for short periods of time but survivability decreases. High salinity stresses affect the survivability by allowing stenohaline predators (ocean predators such as stone crabs (*Menippe mercenaria*) and Black Drum (*Pogonias cromis)*, whelks, oyster leeches, pholad clams, sponges and polycheate worms) to increase predation. During low salinities the oyster will close its shells and shut down for up to a month (Cake, 1983). Care should be taken not to shift the Okatie River Watershed salinity profile through stormwater management.

4.2 Review of Existing Data

The most recent trends assessment from the SCDHEC monitoring station was investigated. This study was a seasonally adjusted, non-parametric trend analysis with the data analyzed on a 5-year cycle that was last updated in 1997 (pers. comm., Richelle Tolton, Watershed Manager, SCDHEC). The only relevant site to the Okatie River is at the confluence of the Colleton River and Chechessee River, just downstream of the Okatie River, designated as site MD-176 (see Figure 4-1). In the report, aquatic life uses are fully supported by dissolved oxygen (DO), bacteria, TP, nitrogen, turbidity and metals data as there are no significant trends reported for these constituents from the sampling period between 1982 and 1996. However, pH had a significant decreasing trend that may be threatening to aquatic life. Recreational uses were fully supported at this site and a significant decreasing trend in FC bacteria concentration suggested improving conditions for this parameter (SCDHEC, December 1997).

The largest sample size of the data set was for pH, which had a trend sample size of 54 samples. The FC data set was comprised of 38 samples. These one-time grab samples provided minimal insight in regards to the Okatie River. These data trends did not take

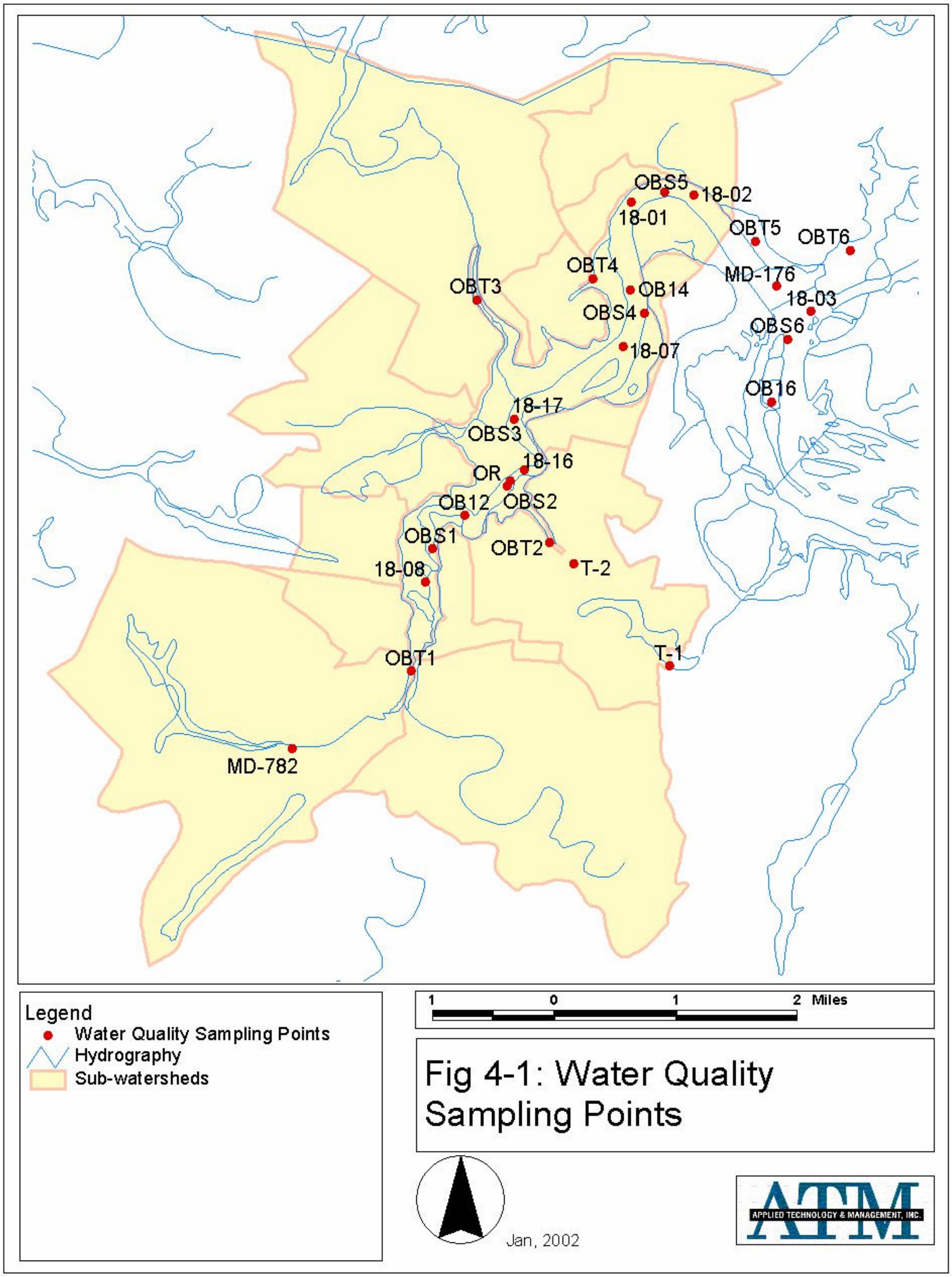


Fig 4-1: Water Quality Sampling Points

into account tidal conditions, salinity conditions, antecedent rainfall conditions and flow parameters. Additionally, Station MD 176 was located outside the Okatie River and may not be entirely reflective of the Okatie Basin as the Chechessee River confluence is near this sample point.

The following summaries of the EPA STORET data analysis, the Clean Water Task Force study, and the Eagle Point study point out the relationship between salinity conditions and antecedent rainfall conditions in the remainder of Section 4.2.

4.2.1 EPA STORET

Water quality data were gathered from the EPA's STORET database. This information was input into Excel for statistical and trend-line analysis. Earliest water quality data were from 1965 Station 18-03 (Chechessee Creek), Station 18-02 (Baileys Oyster Bar), and Station 18-01 (Camp Saint Mary's Dock). Water quality data were available starting in 1984 from 18-07 (Indigo Plantation) and 18-08 (Okatie River at dock without house). Eagle Point, 18-16 (Pinckney Colony Tributary) and 18-17 (Cherry Point Tributary) water quality sampling had commenced in 1997. Sun City water quality monitoring began in 1996. Data from Eagle Point (T-1, T-2, and ORW) and Sun City (MD-782) were also analyzed (Figure 4-1).

The Okatie data summarized in Appendix 1 report varying values of water quality parameters including salinity, temperature, BOD-5, FC, nitrate/nitrite (NO2/3), ammonium/ammonia (NH3/4), TKN, TP, TSS, Cu, and Zn. It is expected that the first flush affect significantly increases the concentrations of the targeted water quality parameters especially after a prolonged dry period. There is a correlation of the FC values correspondingly decreasing due to the current extreme drought (Payne, 2001).

Analysis of the long-term data record identified a potential correlation between sharp increases in FC concentrations (outlier event) and antecedent rain events. This analysis served to demonstrate the amount of variability of in-stream FC concentrations associated with rain events. Since the timing of the sampling varies with the timing of each rain event, there was no attempt to compare the FC loads associated with any rain event.

To understand correlations of outlier water quality values, antecedent rainfall data were gathered from surrounding weather stations at Hilton Head, Beaufort Water Treatment Plant, and Yemassee South Carolina and Savannah Georgia Airport. The rainfall data were gathered from Basins summary and shown for 1 week prior to sample date (see Appendix 1). It is important to note though that rain events were nearly always associated with outlier values. Seventeen of eighteen FC outliers identified from graphic and statistical summaries (see Table 4-1) had significant rain events greater than 0.5 inch within this one-week period, reflecting a likely correlation to runoff. The outlier events had an average of 1.69 inches of rain within the previous week of the sample day. There have been no sampling events specifically targeting first-flush effect phenomenon (sampling within the first 30 minutes after rainfall commences). Additionally, variances in parameters may be caused from dilution and osmotic disruption in more saline waters.

Table 4-2 represents outlier parameters and their respective dates, values, and one-week antecedent precipitation total. Similarly to the single parameter FC analysis, fifteen of the eighteen parameters had over 0.5 inch per week antecedent rainfall.

Table 4-3 presents the results of the one-time sampling study that was initiated by the Clean Water Task Force (SCDHEC, 2000). It illustrates several outlier parameters that are highlighted in red in comparison to the 90th percentiles of SCDHEC water quality parameters from 1993 to 1997 (Chestnut, 1999) and median values that are in Appendix 1.

Salinity and Temperature Influences

Influences of saline and water temperature on FC were investigated for 720 sample events compiled from SCDHEC. Of those 720 events, 18 were identified as outlier events of which a minimum of the top two events per station were utilized. For these 720 samples, an average of the median FC MPN of 10.2 was calculated with a 95% confidence interval and an average standard deviation of 92.8 MPN. The average event mean was 554 MPN and represents over 5 standard deviations higher than the median value. It is hypothesized that the high FC results were due to high antecedent rainfall conditions that flushed fecal contaminants and decreased salinity in the receiving water. Salinity would minimize the osmotic disruption of FC counts and thus decrease FC values.

Table 4-1 Outlier Events with Minimum Top Two Events for Each Station. Corresponding FC, salinity, water temperature, average week rainfall and number of samples.

Station	Paramter	FC (MPN)	Median FC(MPN)	FC Standard Deviation with 95% confidence (MPN)	SC DHEC regs	Date	Salinity (PPT)	Median salinity (PPT)	T ©	Median T ©	Week avg rainfall (in)	# samples
18-01	Fecal Coliform	1600	5	129.3	14 MPN	20-Aug-84	26.5	26.75	29	20	0.54	177
18-01	Fecal Coliform	540	5		14 MPN	8-Mar-83	11	26.75	12	20	3.12	
18-01	Fecal Coliform	350	5		14 MPN	13-Mar-73	9.5	26.75	19	20	2.93	
18-02	Fecal Coliform	920	5	74.9	14 MPN	17-Apr-73	22	27	17	20	0	176
18-02	Fecal Coliform	350	5		14 MPN	20-Aug-84	26.5	27	29	20	0.54	
18-03	Fecal Coliform	240	5	20.8	14 MPN	8-Mar-83	16	27	12	21	3.12	175
18-03	Fecal Coliform	70	5		14 MPN	13-Mar-73	18.5	27	19	21	2.93	
18-07	Fecal Coliform	540	7	61.7	14 MPN	5-Jan-93	21	26	11.5	21	0.54	81
18-07	Fecal Coliform	110	7		14 MPN	9-Jan-95	18	26	14	21	0.54	
18-07	Fecal Coliform	110	7		14 MPN	11-Dec-89	21	26	13	21	2.88	
18-08	Fecal Coliform	2400	17	302.5	14 MPN	5-Jan-93	10	25	11.5	20.5	0.54	81
18-08	Fecal Coliform	920	17		14 MPN	15-Mar-93	0	25	10	20.5	0.95	
18-08	Fecal Coliform	920	17		14 MPN	12-Sep-95	14	25	27	20.5	1	
18-08	Fecal Coliform	540	17		14 MPN	9-Jan-95	16	25	14	20.5	0.54	
18-16	Fecal Coliform	110	17	29.2	14 MPN	27-Oct-97	28	27	22	21	3.58	15
18-16	Fecal Coliform	70	17		14 MPN	25-Feb-98	15	27	14	21	1.5	
18-17	Fecal Coliform	110	13	31.3	14 MPN	25-Feb-98	15	27	14	21	1.5	15
18-17	Fecal Coliform	79	13		14 MPN	27-Oct-97	28	27	22	21	3.58	
	Average values =	554.3889	10.2222222	92.81428571			17.5556	26.34722	17.222	20.6111111	1.685	

Table 4-2 Average Rainfall Values (in)

Outlier Parameter and magnitude	Date	Days prior to 0	1	2	3	4	5	6	7	sum
70 MPN @18-03	13-Mar-73	0.00	0.00	0.00	0.28	0.95	1.23	0.00	0.47	**2.9275**
920 MPN @ 18-02	17-Apr-73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**
540 MPN @ 18-01	8-Mar-83	0.35	0.96	1.52	0.00	0.14	0.00	0.00	0.16	**3.12**
1600 MPN @ 18-01	20-Aug-84	0.07	0.09	0.00	0.30	0.00	0.00	0.00	0.09	**0.5425**
110 MPN @18-07	11-Dec-89	0.00	0.02	0.45	2.42	0.00	0.00	0.00	0.00	**2.8825**
2400 MPN @ 18-08, 540 MPN @ 18-07	5-Jan-93	0.64	0.34	0.00	0.00	0.00	0.00	0.00	0.03	**0.9975**
920 MPN @ 18-08	15-Mar-93	0.43	0.00	0.52	0.00	0.00	0.00	0.00	0.00	**0.95**
540 MPN @ 18-08	9-Jan-95	0.00	0.00	0.38	0.07	0.01	0.03	0.04	0.02	**0.5425**
920 MPN @ 18-08	12-Sep-95	0.20	0.06	0.00	0.04	0.12	0.19	0.33	0.06	**1.0025**
7.7 mg/L @ MD782	2-Jul-96	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	**0.025**
1600 MPN and 1.08mg/L as N @OBT3,	19-Aug-97	0.00	0.05	0.65	0.94	0.15	0.00	0.00	0.00	**1.7925**
110 MPN @ 18-16	27-Oct-97	1.69	1.49	0.26	0.03	0.00	0.10	0.00	0.01	**3.575**
70 MPN @ 18-16	25-Feb-98	0.00	0.00	0.61	0.36	0.00	0.10	0.01	0.42	**1.4975**
.23 mg/L as N @ MD782	9-Jul-98	0.05	0.05	0.00	0.08	0.49	0.07	0.01	0.20	**0.9467**
.23 mg/L as N, .4 mg/L as N @ MD782	27-Aug-98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	**0.07**
7.7mg/L, 1.81mg/L as N, .33 mg/L as P, 120mg/L @MD782	21-Sep-98	0.04	1.19	0.13	0.35	0.02	0.00	0.00	0.00	**1.7267**
1.84 mg/L, 60 mg/L @ MD782	13-Oct-98	0.00	0.00	0.00	0.00	0.00	0.51	0.03	0.07	**0.6**
6 mg/L, 190 mg/L @ MD782	17-Nov-98	0.04	0.03	0.06	0.00	0.00	0.02	0.04	0.00	**0.175**
1100 MPN and 1.25 mg/L @ Eagle Point	14-Oct-99	0.02	0.40	0.68	0.00	0.00	0.00	0.00	0.00	**1.1**

Table 4-3 One Time Sample Event of 19-Aug-97							
sample	BOD	FC	NO2 and NO3	TKN	NH4	TP	TSS
location	mg/L	MPN	mg/L as N	mg/L as	mg/L as N	mg/L as P	mg/L
OB12	2.6	13	0.02	0.52		0.07	20
OB14	2.2	13	0.02	0.59		0.13	44
OB16	1.4	2	0.02	0.36	0.1	0.09	9.8
OBS1	3.4	90	0.02	0.97		0.16	110
OBS2	2.7	40	0.02	0.85	0.74	0.12	51
OBS3	2.6	13	0.02	0.97	0.68	0.1	78
OBS4	1.8	8	0.02	0.68	0.42	0.12	48
OBS5	1.4	4	0.02	0.68	0.48	0.12	54
OBS6	1.6	2	0.02	0.76	0.46	0.1	51
OBT1	1.6	280	0.1	0.88	0.33	0.28	50
OBT2	1.4	23	0.02	0.82		0.16	56
OBT3	5.9	1600	0.02	1.08	0.14	0.19	53
OBT4	2.4	30	0.02	0.53		0.1	23
OBT5	1.9	23	0.02	0.55		0.12	42
OBT6	1.6	2	0.02	0.56		0.08	24

Average Rainfall Values (in)									
	Days prior to 19-Aug-97								
	0	1	2	3	4	5	6	7	week total
	0	0.053	0.6525	0.94	0.1475	0	0	0	1.7925

The average salinity for the 18 events was 17.56 ppt. The average of the median salinities for the sample stations was 26.34 ppt. The total average of all water temperatures was 17.2EC and the average of the median water temperatures was 20.6EC, which likely reflects the cooler water temperatures after the cloudy days and cool rains. The water temperature is a seasonal variable that would need to be taken into account (see Table 4-1).

According to David Payne, shellfish sanitation program manager for SCDHEC Low Country District EQC office, there are noted correlations between rainfall events, salinity, and resultant FC counts. Elevated FC values negatively impacted the classification of the shellfish stations in the Okatie Basin, specifically after el niño rains in 1998. Additionally, in 1995, Station 18-08 was classified as a restricted area. This was correlated to rain events, corresponding decreased salinities, and likely erosion from development activities adjacent to the headwaters of the Okatie. As noted earlier, FC is likely correlated to TSS from erosion via various pathways.

In July 2001, Station 18-16 to Station 18-08 had been upgraded to unrestricted shellfish stations. The improvements in water quality required for this upgrade are likely due to the drought conditions. Under drought conditions less freshwater runoff would have entered the waters near these stations. This would have decreased the FC load to these waters. Less freshwater runoff would have kept salinity high in these waters as well. Higher salinity would have increased the saline disruption occurring in FC bacterial cell walls, further decreasing the FC population in these waters.

4.2.2 Okatie River Watershed Water Quality Literature Review

4.2.2.1 Eagle Point PUD Study

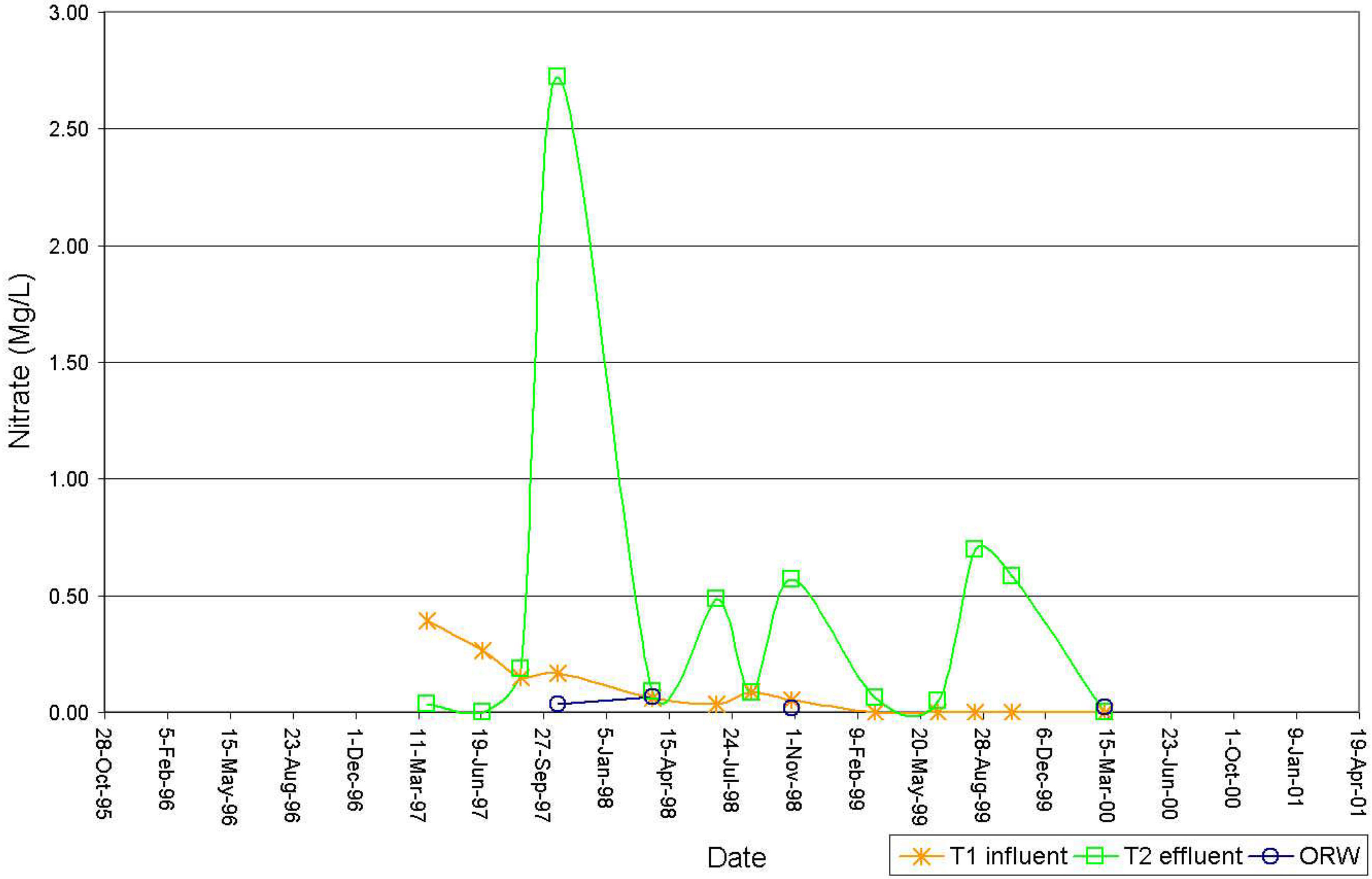
Copies of monitoring reports for the Eagle Point PUD water quality monitoring program were obtained from the Beaufort County Engineering Department. This monitoring program is the only one for a PUD in the Okatie where the effect of the development on surrounding environmental quality is being rigorously monitored. Data were entered on Excel spreadsheets and summarized. A statistical analysis was done for BOD-5, nitrates, NH-3, TKN, TP, TSS, Zn, CU, and FC. Graphs show upstream (T1), downstream (T2) and stream convergence of the Okatie (ORW) values. Increases in nitrogen and FC are apparent and exceedences of Zn, pH, DO, BOD-5, and ammonia are notable (see Table 4-4, Graphs 4-1 and 4-2). Table 4-4 displays differences in relevant median and maximum parameters and highlights those (in red) that increased or show a trend toward increased concentrations at the upstream station. However, these trends should be viewed cautiously since most of the sampling occurred during dry conditions and there are no antecedent background levels for comparison. Other parameters monitored show weak relationships and no trends are apparent (see Appendix 1).

Mean and median values of nitrogen parameters, with one exception, increased between influent at T1 and effluent at T2. The mean influent nitrate concentration (T1) was 0.152 mg/L while the effluent (T2) increased to 0.552 mg/L and the receiving water concentration (ORW) was 0.036 mg/L. Similarly, TKN mean influent concentration (T1) was 0.812 mg/L while the effluent (T2) increased to 1.512 mg/L and the receiving water concentration (ORW) was 1.041 mg/L. Ammonia mean influent concentration (T1) was 0.466 mg/L while the effluent (T2) increased to 0.525 mg/L and the receiving water concentration (ORW) was 0.294 mg/L. While all three mean nitrogen parameters show a nitrogen increase from upstream to downstream, the data sets for these parameters all have outliers at either T1 or T2 which influence the mean (see tables and charts in Appendix 1B). The median values for nitrogen as nitrate and ammonia increased between T1 and T2. However, TKN decreased somewhat between the two points (see

Table 4-4 Water Quality Analysis for Eagle Point and Sun City

Sample Location		Median FC MPN	Maximum FC MPN	Median BOD mg/L	Median NO2 and NO3 mg/L as N	Median TKN mg/L as N	Median NH4 mg/L as N	Median TP mg/L as P	Median TSS mg/L	Median Zn mg/L	# samples
T2	Eagle Point effluent	69	1100	2.8	0.335	0.668	0.534	0.22	21	0.0295	13
T1	Eagle Point influent	37	246	4.2	0.12	0.73	0.271	0.209	23	0.024	13
ORW	Eagle Point Tributary and Okatee confluence	6	1000	2.9	0.0288	0.525	0.238	0.093	44	0.024	11
MD-782	SUN CITY DISCHARGE TO OKATIE RIVER @ SC170			2.4	0.04	0.9	0.1	0.11	21	0.01	26

Graph 4-1. Eagle Point Nitrate



Graph 4-2. Eagle Point Fecal Coliform

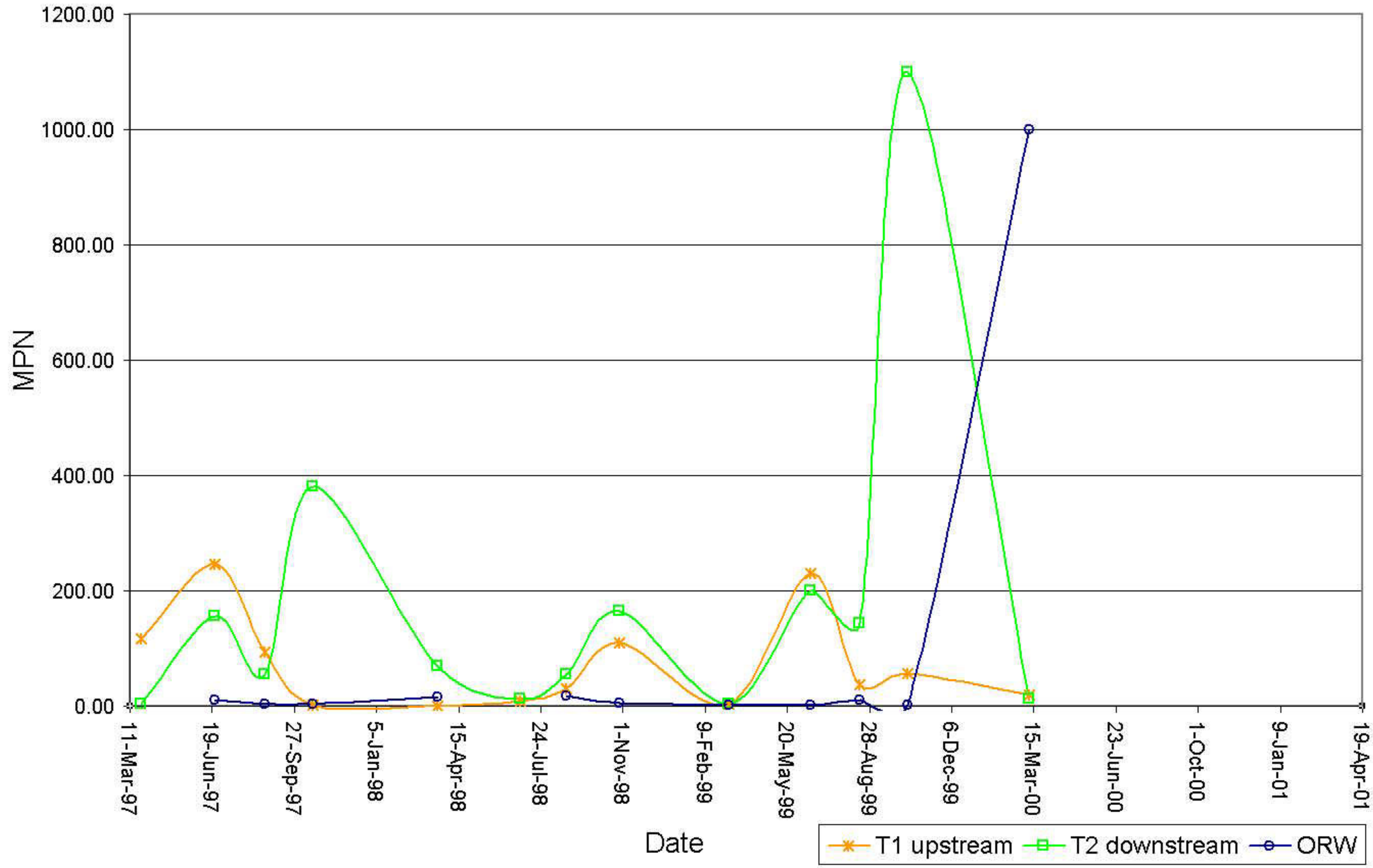


Table 4-4). Despite the caveats of the smaller size of the data sets and the presence of outliers, the increase in both mean and median values for all nitrogen parameters but one suggests a potential eutrophying effect on the estuarine community downstream. Estuarine systems are typically nitrogen limited and may show detrimental effects at nitrogen concentrations of 0.1 mg/L or greater (NOAA/EPA 1988). There were no South Carolina state guidelines for nutrient levels except in SCDHEC 90th percentiles (Chestnut, 1999).

Data collected from March 1997 to March of 2000 showed exceedences of standards as noted in the Eagle Point 2000 Annual Summary Report (Lopez, 2000). There were three exceedences of the Cu standard (>.0029 mg/L) and one for Zn (>.0950) at ORW, two Cu (>.0092 mg/L) and two Zn (>.0065 mg/L) exceedences at T-1, and three Cu exceedences (>.0029 mg/L) one Zn (>.0065 mg/L) exceedence at T-2. pH standard (<6.0) excursions occurred at ORW, T-2 and the outfall. There was only one DO less than 5.0 mg/L at ORW, but two very low values of 2.8 and 3.0 mg/L were measured at T-2. High TP values (>0.57mg/L) at T-1 and T-2, and ORW (.28mg/L) were taken. BOD-5 exceeded the 90th or 95th percentile of other SCDHEC data in most of the samples at T-1 and T-2 and in several samples at ORW. Ammonia values were also greater than the 95th percentile in almost all samples in T-1, T-2, and the outfall, although they did not exceed the acute toxicity standard (Chestnut, 1999; Lopez, 2000).

Additionally, a macroinvertabrate bio-monitoring program has shown that no significant differences exist among mean counts of taxa richness and total abundance as a function of sampling time for sample years 1997, 1999, and 2000 (Lopez, 2000). There was a significant difference reported for taxa richness as a function of sampling time in 1998; however, a poor water quality rating based on macroinvertabrate data may not be justified due to lack of adequate reference conditions for low gradient coastal plain streams (Chestnut, 1999).

4.2.2.2 Bureau of Water Study

A water quality sampling study was initiated by the Clean Water Task Force that was formed as a result of a citizens group that was alarmed with the increased closure of estuarine waters to shellfish harvesting (SCDHEC, 2000). This study was a one-time sampling event in the summer of 1997 that had water sampling locations in both the Broad Creek and the Okatie River (see Figure 4-1).

It should be noted that the Broad Creek samples were taken after a 1.3 inch rainfall the night before samples and the Okatie River samples were taken after a relatively dry weather period (SCDHEC, 2000) in which approximately 1.8 inches of rain fell during the week prior to sampling. Additionally, there were exceptionally high spring tides at the time of sampling. These environmental influences make conclusions comparing the two watersheds difficult.

The SCDHEC (2000) study stated that the tidal creek (OB)T-3 sample station (approximately 500 feet upstream of Heffalump Road crossing) stood out as the only site receiving a water quality rating of poor on the Okatie River. FC bacteria at this site included colonies identified as having human sources based on high Multiple Antibiotic Resistance (MAR) results that correlate human induced antibiotic resistance in the tested bacteria compared to wildlife bacteria.

Parameters measured included temperature, turbidity, DO, BOD-5, pH, conductance, chlorophyll-a, total alkalinity, ammonia (NH-3/4), TKN, nitrates, TP, total organic compounds (TOC), chlorine and FC. Heavy metals and organic compounds were analyzed in the sediments and oyster tissues. Values utilized in the analysis include BOD-5, FC, TKN, NH-3/4, TP, and TSS. See Table 4-3 for summary. The following is a review of these parameters measured in the Okatie River.

Five-day Biochemical Oxygen Demand (BOD-5)

BOD-5 was reported as having a high concentration at sub-tidal creek (R-2) and had a very high concentration at the sub-tidal creek (R-2) and the tidal creek (T-3) relative to other SCDHEC monitoring data.

Fecal Coliform

FC outlier locations include one main-stem intertidal river site (R-1) which exceeded 43 CPU and two of the tidal creek sites (T-1 and T-3) exceeded 200 CPU. Site T-3 exceeded 400 CPU. Two regions of high MAR were found at T-3 and I-4 (sewage treatment plant land-based discharges) and T-2 (unknown source).

Total Kjeldahl Nitrogen (TKN)

TKN values were reported as “very high at tidal creek T-3”. All other location values were comparable to values observed in other SCDHEC saltwater monitoring data.

Ammonia/ammonium (NH3/4)

NH3/4 values did not exceed state standards. Five sub-tidal river sites (R-2 through R-6) had very high concentrations. Tidal creek (T-1) had a high concentration while T-3 was greater than 95% of the values seen in other SCDHEC monitoring data.

Total Phosphorus (TP)

Only two tidal creeks (T-1 and T-3) reporting high TP concentrations. There were no values that exceeded the 95th percentile of values seen in other SCDHEC monitoring data. It was noted that these tidal creeks seem to be functioning as conduits delivering nutrients to the main creeks.

Trace Metals and Polyaromatic Hydrocarbons (PAHs)

In the sediment analysis, two outlier contaminants arsenic (sites T-4, T-6, I-2, I-4, I-6) a trace metal, and lindane (sites S-1, S-2, S-3, S-5, S-6), a chlorinated hydrocarbon persistent insecticide used in agricultural and urban applications, were found in the Okatie. With increasing urbanization, these trace metals and pesticides may adversely affect early warning stress indicators and may ultimately affect epibenthic and benthic fauna.

Invertebrates

Invertebrate biota studied indicated that the Okatie River has a generally healthy biological assemblage that is consistent with other non-degraded estuarine sites that have been sampled in South Carolina. There was biological stress noted in higher than anticipated levels of a few metal contaminants in oyster tissue throughout the drainage system, along with sub-lethal (cellular) response in the oyster populations.

The SCDHEC (2000) study stated that the tidal creek T-3 sample station (approximately 500 feet upstream of Heffalump Road crossing) stood out as the only site receiving a water quality rating of poor on the Okatie River. Fecal coliform bacteria at this site included colonies identified as having human sources based on high MAR results that correlate human induced antibiotic resistance in the tested bacteria compared to wildlife bacteria.

4.3 Stormwater Pollutants of Concern

The evaluation of stormwater runoff pollution impacts focuses on pollutants commonly found in stormwater. Emphasis is on FC due to its being the most restrictive parameter in the watershed. Correlations exist between compounding water quality factors and therefore all pollutants need to be minimized to decrease FC concentrations. Annual load estimates are required for the pollutants evaluated as part of the NPDES municipal stormwater permitting (CDM, 1998). The following stormwater pollutants are evaluated:

- Pathogens
- BOD-5
- Nutrients (TKN, NH3/4, and TP)
- TSS and total dissolved solids (TDS)
- Heavy metals, volatile organic compounds (VOC), PAHs, and others

4.3.1 Pathogens

Bacteria are usually present in high concentrations during storms, come from many different sources, and follow many complex pathways to reach receiving waters. In a rural environment, fecal pollution may be derived from livestock and poultry, with contributions in lesser amounts from wild animals and birds. In urban areas, fecal contamination probably originates from dogs, cats, rodents and other small animals (Say-Hua Lim, 1982). In wetlands, for example, there are naturally occurring bacteria that are mostly associated with solid surfaces of plants, decaying organic matter and soils but these types of bacteria are typically not considered pathogenic. E. coli is the predominant coliform in feces included in gram negative facultatively anaerobic rods. Specific species pathogens include *Giardia lambia, Entamoeba histolytica*, *Cryptosporidium, Escherichia, Salmonella, Shigella, Klebsiella*, *Leptospira* spp., *Enterobacter, Aeromonas*, *Streptococcus* spp. and various viruses including Hepatitis A (Viessman and Hammer, 1993; Say-Hua Lim, 1982; Kadlec, 1994).

A case study of the Okatie River and Broad Creek in Beaufort County showed greater diversity/species richness in the coliform group members resulting from the availability of bacteria from the deciduous hardwood forest when compared to upland watersheds in urbanized locations, which contain more monoculture habitat (i.e., lawns with grass and ornamental plants). These findings indicated that FC bacteria pollution is associated with urbanization and that closure of shellfish harvesting waters may be perhaps the most significant, quantifiable impact from urbanization (SCDHEC, 2000). The 2001 Area 18 Shellfish Management Report (Payne, 2001) cites “stormwater runoff following rainfall may be contributing to high FC concentrations at Stations 18-08 and some impact at Stations 18-16 and 18-17” (see Figure 4-1).

The mechanisms involved in abating pathogen populations are also varied and include detention of stormwater runoff, dilution, osmotic disruption in saline waters, predation, ultraviolet (UV) light penetration, sedimentation, adsorption/filtration, desiccation, chemical disinfections, colder water temperatures, low nutrient levels, low carbon supplies, low pH levels and natural die-off. Some BMPs that utilize these mechanisms include riparian buffer zones, stormwater wetlands, wet detention ponds, bio-retention, peat filters (White et. al., 2000; R.C. Borden et al., 1997; CWP, 1999).

About 20% of all FC water quality samples at USGS’s ambient sampling stations across the country exceeded 200 MPN/100mL despite most of these samples being conducted in dry weather conditions. The USGS survey also report that the highest FC levels were routinely collected in agricultural and urban watersheds while forested and pastured watersheds had much lower FC levels of about 50 to 100 MPN/100mL (CWP, 1999). Two studies report mean urban runoff FC concentration at 20,000 MPN/100mL (CWP, 1999) (based on 1,600 samples in early 1980s from Nationwide Urban Runoff Program) and 15,000 MPN/100mL from the Center for Watershed Protection (CWP, 1999).

There are several factors that increase fecal pathogens in shellfish waters including increased stormwater runoff, higher input concentrations, and increased transport efficiencies. Increased stormwater runoff especially during the first flush effect is a major constituent to FC loading in urban areas (CWP, 1999). In a naturally wooded or wetland area, these contaminants would be diminished in manners as listed previously, thus emphasizing the importance of buffer areas in regards to water quality as a BMP to coliform reduction. Therefore, water quantity has a direct affect on water quality, and mechanisms to decrease runoff will inherently decrease coliform transport to shellfish waters.

For example, a study of a North Carolina watershed with less than 5% imperviousness, which is well below the published threshold for the initiation of water quality degradation

(Schueler, 1995), found excessive fecal counts in its samples. This was likely due to hydrologic modifications such as channelization, ditching, and bulk-heading modifications that cause stormwater runoff to be delivered faster and in greater volumes during storm events, allowing less time for bacterial storage in the watershed, naturally occurring or not, to be reduced (White et al., 2000). Other factors that may better predict bacteria levels include population density, age of development and percent residential development (CWP, 1999).

Bacteria contamination is most effectively treated by filtration (Bingham et al., 1996) as the bacteria are typically attached to a floating medium usually in the form of suspended solids. Approximately 15 to 30% of FCs are attached to suspended sediments and can be settled out. Approximately 50% are unattached and have settling rates similar to fine clay particles, which are about 2 to 4 feet per day. Therefore, under ideal conditions, a detention pond would settle out 90% of bacteria in 2 days (Schueler, 2000b).

Many previous studies have assumed that NPS pollutants are closely associated with TSS. However in a North Carolina study of wet detention pond treatment efficiencies, correlations are more closely related with volatile suspended solids (VSS), suggesting that many of the pollutants are more closely associated with the organic fraction of the suspended solids. The organic solids typically have a lower specific gravity, and consequently pollutants associated with VSS may be less amenable to removal by sedimentation alone (Borden et al., 1997). Additionally, bacteria thrive better under higher nutrient and carbon waters (Schueler, 2000b). BMPs should therefore emphasize removal of VSS and nutrients to maximize water treatment efficiency of fecal contaminants.

4.3.2 Five-Day Biochemical Oxygen Demand

BOD represents the depletion of DO levels due to the decomposition of organic material in solution. If the organic loadings are excessive, they deprive fish and other aquatic organisms of the oxygen they require. The potential for DO depletion is measured by the BOD-5 test that quantifies the amount of easily oxidized organic matter present in the water.

4.3.3 Nutrients

During the past two decades much has been learned about the effects of both natural and anthropogenic nutrient inputs (e.g., nitrogen, phosphorus) on such important estuarine features as phytoplankton production, algal biomass, shellfish and sea grass abundance and distribution and oxygen conditions (UMCES, 2001). When excessive nutrient sources are input into a water body (usually through human induced anthropogenic sources) this is referred to as eutrophication. Of particular importance, it has been determined that (1) algal primary production and biomass levels in many estuaries (including the downstream Chechessee Bay) are responsive to nutrient loading rates, (2) high rates of algal production and algal blooms are sustained through summer and fall periods by benthic recycling of essential nutrients, (3) aquatic life uses may be hampered when the entire water body experiences daily fluctuations in DO levels as a result of nightly plant respiration (extreme oxygen depletion can lead to death of desirable fish species, and (4) shellfish communities may be impacted from hypoxic and anoxic conditions (UMCES, 2001) and toxic algae ("red tide") have been associated with eutrophication in coastal regions and may result in paralytic shellfish poisoning (Mueller et al., 1987).

Nutrients and organic matter enter the Okatie River from a variety of potential sources, including fluvial inputs, local NPS drainage (i.e., urban fertilizers, pet excrement, etc), applications of treated effluent to golf courses (Payne, 2001), septic systems and direct rainfall on bay waters. These nutrients are rapidly incorporated into particulate matter via biological, chemical and physical mechanisms. A portion of this newly produced organic matter sinks to the bottom, decomposes and thereby contributes to the development of hypoxic or anoxic conditions and loss of habitat for important shellfish and demersal fish communities (UMCES, 2001).

The regenerative and large short-term nutrient storage capacities of estuarine sediments ensure a large return flux of nutrients from sediments to the water column that can sustain continued high rates of phytoplanktonic growth and biomass accumulation. Continued growth and accumulation supports high rates of deposition of organics to deep waters, creating and sustaining hypoxic and anoxic conditions typically associated with eutrophication of estuarine systems. To a considerable extent, it is the magnitude of these processes that determines water quality conditions in many zones of the bay (UMCES, 2001).

Investigations of nutrient water quality parameters reviewed TP and the nitrogen parameters TKN, nitrates and nitrites (NO2/3), and NH3/4. TKN is a measure of the organic fraction of nitrogen; nitrate and nitrite measure the inorganic fraction. Phosphorus is typically the limiting nutrient for fresh water systems while nitrogen is the limiting nutrient for estuarine systems (Paerl, 1993). Algal blooms may cause anoxic conditions (and subsequent fish kills) especially during summer months after continually overcast days, which force these algae to respire and utilize the DO in the water column.

Eutrophic waters are typically more amenable to survivorship of bacterial pathogens as this provides them a food source and possible substrate to attach to and secondarily blocks solar radiation, which is damaging to the bacterial coliforms. Low nutrients act as a growth inhibitor in that it slows their growth, reduces survival and increases predation (CWP, 1999).

TP is a more restrictive component then other nutrients for water quality improvements due to its inability to be volatilized and settling ability. Removal of both particulate and soluble fractions of phosphorous must be accomplished to meet BMP guidelines (CDM, 1998) and is typically more difficult to remove compared to nitrogen, therefore BMP guidelines are based on the removal of phosphorus. Nitrogen, however, may be fixed from the atmosphere and input from an external source (i.e., dog and duck feces), which is explained in further detail in the BMP section.

The recommended level of nitrogen in estuaries to avoid algal blooms is 0.1 to 1 mg/L, while the phosphorus concentration is 0.01 to 0.1 mg/L. Higher concentrations of both will support less diversity (NOAA/EPA, 1988). It has been observed that if dissolved inorganic nitrogen levels in Virginia's Chesapeake Bay tributary watersheds are maintained at less than 0.15 mg/L and dissolved inorganic phosphorus concentrations are less than 0.02 mg/L, submerged aquatic vegetation nutrient requirements are met and summer chlorophyll-a levels remain less than 15 micrograms per liter (Batiuk et al., 1992). Okatie River waters are typically above the 1 mg/L for nitrogen and 0.1 mg/L for phosphorus, which may be indicative of water quality impairment. However, there are no numeric standards or TMDLs for South Carolina estuarine systems, although there are narrative standards that reflect maintaining balanced indigenous flora and fauna (Kathy Strecker personal communications). SCDHEC water quality data from 1993 to 1997 have 50, 90, and 95th percentiles of freshwater and saltwater. The 90th percentile for saltwater TKN is 1.06 mg/L and for TP is 0.16 mg/L, which exceed the NOAA levels

(Chestnut, 1999). SCDHEC is developing numeric standards for estuarine systems at this time.

4.3.4 Total Suspended Solids and Total Dissolved Solids

Sediment is the most common stormwater pollutant discharged to surface waters. Excessive sediment loadings can lead to the destruction of habitat for fish and aquatic life and to the depletion of the storage capacity of stormwater ponds, wetlands, and other water bodies. Sediments may clog filtering apparatus of the eastern oyster and decrease survivability (Cake, 1983). Sediments also function as conveyers of pollutants that are physically bound to the suspended particles. TSS is a laboratory measurement of the amount of sediment particles suspended in the water column. In developing areas, excessive sediment loadings are primarily associated with poor erosion and sediment controls at construction sites or unstable channels. In developed areas, sediment pollution is caused primarily by stream bank erosion resulting from high runoff peaks (CDM, 1998).

4.3.5 Heavy Metals, Volatile Organic Compounds, Polycyclic Aromatic Hydrocarbons, Etc.

Fish and shellfish may also bioaccumulate heavy metals and toxins (CDM, 1998). There is currently a U.S. Food and Drug Administration (FDA) January 2001 advisory for Atlantic King Mackerel due to mercury throughout the state. Other water quality concerns that may become of greater concern as population densities increase include carcinogens such as inorganic heavy metals (chromium, Zn, arsenic, mercury, lead etc.), volatile organic chemicals VOCs (benzene, vinyl chloride, etc.), organic chemicals (aldicarb, PCBs, toluene etc.), PAHs, phenols, trihalomethanes and radionucleotides (Viessman and Hammer, 1993). Many of these toxic chemicals are of concern because of their ability to be biomagnified in the food web and because of their associated faunal fatality (CDM, 1998). Lead, Cu, Zn, and cadmium typically exhibit greater concentrations than other metals found in urban runoff.

Heavy metals are elements having atomic weights between 63.546 and 200.590 and a specific gravity greater than 4.0 (Connell et al., 1984). Living organisms require trace amounts of some heavy metals, including cobalt, Cu, iron, manganese, molybdenum, vanadium, strontium, and Zn. Excessive levels of essential metals, however, can be detrimental to the organism. Non-essential heavy metals of particular concern to surface water systems are cadmium, chromium, mercury, lead, arsenic, and antimony (Kennish, 1992). Excess metal levels in surface water may pose a health risk to humans and to the environment. The metals lead, Cu, Zn and cadmium are toxic at varying concentrations for different species of plants, animals and microorganisms.

All heavy metals exist in surface waters in colloidal, particulate, and dissolved phases, although dissolved concentrations are generally low (Kennish, 1992). The solubility of trace metals in surface waters is predominately controlled by the water pH, the type and concentration of ligands on which the metal could adsorb, and the oxidation state of the mineral components and the redox environment of the system (Connell et al., 1984).

The behavior of metals in natural waters is a function of the substrate sediment composition, the suspended sediment composition, and the water chemistry. Sediment composed of fine sand and silt will generally have higher levels of adsorbed metal than will quartz, feldspar, and detrital carbonate-rich sediment. Metals also have a high affinity for humic acids, organo-clays, and oxides coated with organic matter (Connell et al., 1984).

The water chemistry of the system controls the rate of adsorption and desorbtion of metals to and from sediment. Adsorption removes the metal from the water column and stores the metal in the substrate. Desorption returns the metal to the water column, where recirculation and bioassimilation may take place. Metals may be desorbed from the sediment if the water experiences increases in salinity, decreases in redox potential, or decreases in pH.

1. *Salinity increase:* Elevated salt concentrations create increased competition between cations and metals for binding sites. Often, metals will be driven off into the overlying water. (Estuaries are prone to this phenomenon because of fluctuating river flow inputs.)
2. *Redox potential decrease:* A decreased redox potential, as is often seen under oxygen deficient conditions, will change the composition of metal complexes and release the metal ions into the overlying water.
3. *pH decrease:* A lower pH increases the competition between metal and hydrogen ions for binding sites. A decrease in pH may also dissolve metal-carbonate complexes, releasing free metal ions into the water column (Connell et al., 1984).

Research has shown that aquatic plants and bivalves are not able to successfully regulate metal uptake (Connell et al., 1984). Thus, bivalves tend to suffer from metal accumulation in polluted environments. In estuarine systems, bivalves often serve as biomonitor organisms in areas of suspected pollution (Kennish, 1992). Shellfishing waters are closed if metal levels make shellfish unfit for human consumption.

VOCs are a group of commonly used chemicals that evaporate, or volatilize, when exposed to air. Since they dissolve many other substances, VOCs are widely used as cleaning and liquefying agents in fuels, degreasers, solvents, polishes, cosmetics, drugs, and dry cleaning solutions. VOCs are found at airports and service stations; machine, print and paint shops; electronics and chemical plants; dry cleaning establishments; and in household products. Some are toxic environmental pollutants and may be carcinogenic.

PAHs are generally indicative of urban development where fossil fuel combustion occurs, such as roadways. Concentrations of PAHs in waters receiving stormwater runoff may be high enough to cause acute or chronic toxicity problems for aquatic organisms including the eastern oyster (CDM, 1998; Cake, 1983). PAHs are not included in the evaluation due to the lack of available monitoring data.

4.4 Pollutant Loading Estimates

The water quality data were analyzed in the SWMM XP2000 model. The Okatie watershed was divided into the 95 catchments and 12 sub-watersheds as shown on Figure 2-4. Event mean concentrations (EMCs) were derived for each sub-watershed and CNs were derived for each catchment. The SWMM XP2000 model utilized these parameters, as well as rainfall records, to calculate pollutant loading. The EMCs were entered from Table 3-6 in the Beaufort County BMP Manual, *EMCs and Average Annual Loads for Various Land Uses* (CDM, 1998). Event mean concentrations for FC were entered from Section 2.3.3 in the report on Stormwater Quality Evaluation for the Proposed Barefoot Landing Resort, *EMCs for Fecal Coliform* (ATM, 1999). They were compared with geometric means of water quality parameters from the available researched literature database to determine loading rates on a sub-basin watershed area. The EMCs were input into the XP-SWMM model for pollutant loading estimates. The model estimates pollution loading based on a calculated runoff volume times the EMC for the selected pollutant parameters. Runoff CNs were derived for each catchment based on soil classification and land use classification for both PLU and FLU conditions (see Appendix 2, Table 2A-4). Invert elevations were input as model parameters. The model estimates the pollutant loads for the PLU condition and predicts future pollutant loadings corresponding to the FLU condition.

The model estimates the unit pollutant loadings, or the mass of a given contaminant (in pounds), per acre, per year, for each of the catchments; and the total loading, i.e., mass of pollutants, in pounds per year for an entire sub-watershed. The unit loading is used to assess the potential for water quality degradation; whereas the total loading is an estimate of the mass of pollutants that will be generated from the entire basin area.

Non-point source (NPS) is a term used to characterize pollution that enters surface waters from diffuse sources, usually intermittently, as a function of storm events. The stormwater is generated over a large area, and the pollutants are transported overland until they ultimately reach a surface water body. The two major NPS categories are rural and urban: rural include grazing and agriculture which transport pollution from fertilizers or animal wastes; while urban sources include runoff from impervious residential, commercial, industrial and roadway areas.

Land use is one of the main factors influencing runoff as a percentage of rainfall. The coefficient of runoff increases with increased impervious area. Hence the factors that drive the model's pollutant loading estimation are: 1) the percentage of area within a land use category and its effect on impervious area, and 2) rainfall, and 3) BMPs. Pollutant loads are estimated based on the estimated volume of runoff over a given time period (in this case annually and the wet season) multiplied by expected EMCs for the pollutants of concern. Model parameters take into account the existing wet ponds and swales present in each catchment and decrease the loading rates by the assumed reduction percentages in Table 4-5. These values were obtained from the median values between high and low percent removals for individual BMPs (CDM, 1998) for TP, BOD, TSS and Zn. The FC removal efficiencies were estimated from the references of Kadlec and Knight (1996) for treatment wetlands and from the estimate of Schueler (2000b) that under ideal conditions a detention pond will settle out 90% of bacteria in 2 days retention time. It should be noted that the actual FC removal efficiencies will be less if there is considerable resuspension and transport of bottom sediment, or if there is significant wash-in from sources such as dog feces and bird guano, and especially if there are resident ducks in or near the pond.

Table 4-5 BMP Parameter Removal Efficiencies					
BMP	Coliform	TP	BOD	TSS	Zn
Ponds	90%	50%	30%	85%	70%
Swales	10%	20%	15%	40%	30%

SWMM Model Interpretation

Water quantity and quality data were obtained from the SWMM model analysis and entered on Excel spreadsheets (shown as tables in Appendix 3, Section D). The SWMM model results were placed in Tables 3D-1 and 3D-9. The data summarized PLU and FLU of each catchments area, flow, FC, TP, BOD-5, TSS, and Zn values. These values were then normalized from the model time period of 47.62 years to an annual basis in Tables 3D-2 and 3D-10. These data sheets were then normalized on a per acre basis on Tables 3D-3 and 3D-11.

BMP removal efficiencies were determined by obtaining the catchments PLU percent BMP coverage as determined in the PLU section of this report (also see Table 3D-8) and multiplying this coverage by the predicted removal efficiencies in Table 4-5. Similarly, FLU removal efficiencies for each catchment were determined based on FLU coverages (see Table 3D-16) and the present requirements for new development that they would be required to be constructed under the current BMP manual (CDM, 1998).

The average annual PLU and FLU loading rates with BMPs in place in pounds per year were then determined by multiplying the loading rates from 3D-2 and 3D-10 (1 - removal efficiencies). The resultant loading rates were placed in 3D-4 and 3D-12. Tables 4-6 and 4-7 provide the catchments with the top ten loading rates with BMP.

Table 4-6: PLU annual load rates

Present Land Use with BMPs									
Loc.	Coliform	Loc	TP	Loc.	BOD	Loc.	TSS	Loc	Zn
#	(#/100ml-yr)	#	(lbs/yr)	#	(lbs/yr)	#	(lbs/yr)	#	(lbs/yr)
55	2.66142E+11	55	994.1677	55	30421.5	55	211804.6	55	174.202
73	1.11007E+11	73	397.6534	73	11797.07	73	83493.78	73	67.02661
29	99232786697	18	280.539	45	9927.29	18	61323.74	12	49.02287
1	84639507452	12	275.0133	18	8733.201	12	58051.36	18	46.94762
12	78474894988	45	272.1486	12	7729.057	45	33714.77	1	36.5231
8	55834456816	1	256.6488	11	7266.575	65	29087.32	45	35.57506
18	51657402612	11	193.29	1	6821.566	36	27568.54	36	25.28348
2	36894844352	36	176.7979	36	6159.656	29	25973.62	29	25.0701
65	32656568272	65	113.8244	65	3417.252	14	25351.53	11	24.25237
52	29054138616	52	112.5595	52	3257.938	90	23741.07	65	21.65238
7	28857241498	14	97.28713	71	2917.816	52	23088.94	52	19.26756

Table 4-7: FLU annual load rates

Future Land Use with BMPs									
Loc.	Coliform	Loc.	TP	Loc.	BOD	Loc.	TSS	Loc.	Zn
#	(#/100ml-y	#	(lbs/yr)	#	(lbs/yr)	#	(lbs/yr)	#	(lbs/yr)
1	5.82E+11	56	994.1677	56	30421.5	56	211804.6	56	174.202
56	2.66E+11	1	484.1254	1	21096.87	1	118451.2	1	151.658
7	1.47E+11	74	469.2767	74	14131.4	74	98638.84	74	78.60259
22	1.29E+11	73	380.0587	30	14099.05	73	62535.78	30	64.97227
74	1.26E+11	30	326.9017	73	12636.36	30	49849.1	73	55.90177
30	1.19E+11	46	288.5514	46	10526.76	12	42070.25	7	55.55397
61	8.93E+10	66	241.6531	66	9919.624	46	35748.22	22	52.54664
4	8.38E+10	12	240.372	7	9266.493	66	34553.82	66	42.85636
6	7.77E+10	18	216.8179	22	9258.827	7	34307.04	12	37.89624
3	7.54E+10	11	205.088	18	7901.97	22	34154.04	46	37.71982
73	7.28E+10	37	198.5983	12	7786.037	13	31160.78	6	31.2156

The catchments were ranked by their loading values for each of the 5 pollutants, under both PLU and FLU. They were listed from highest to lowest loading for each pollutant (see Tables 3D-6, 3D-7, 3D-13, and 3D-14). Thematic maps of the catchments were also developed to illustrate the spatial distribution of pollutant loading (see figures in Appendix 3A). It was discovered that the largest catchments in many cases made the greatest pollutant contributions. This result was not surprising as more pollutants usually occur as contribution area increases. The top ten catchments for each pollution parameter are displayed in Tables 4-8 and 4-9 for both PLU and FLU.

Table 4-8: PLU Load Top 10 Ranks on per acre basis

PRESENT RANKS

rank	Loc. #	Coliform (#/100ml-yr-ac)	Loc. #	TP (lbs/yr-acre)	Loc. #	BOD (lbs/yr-acre)	Loc. #	TSS (lbs/yr-acre)	Loc. #	Zn (lbs/yr-acre)
1	8	7.25E+8	83	1.41E+0	83	6.47E+1	83	5.55E+2	83	6.50E-1
2	2	5.27E+8	82	1.21E+0	82	5.53E+1	82	4.96E+2	82	5.68E-1
3	83	4.36E+8	18	9.11E-1	47	3.19E+1	18	1.99E+2	57	3.41E-1
4	35	4.24E+8	36	8.80E-1	49	2.95E+1	36	2.01E+2	8	1.90E-1
5	82	3.78E+8	47	8.74E-1	57	2.86E+1	47	1.08E+2	36	1.53E-1
6	30	2.93E+8	49	8.07E-1	18	2.83E+1	49	1.01E+2	18	1.52E-1
7	89	2.75E+8	12	7.81E-1	48	2.59E+1	12	1.65E+2	12	1.39E-1
8	36	2.43E+8	56	7.71E-1	34	2.58E+1	56	1.64E+2	56	1.35E-1
9	12	2.23E+8	48	7.10E-1	46	2.56E+1	48	8.87E+1	2	1.31E-1
10	56	2.06E+8	34	7.09E-1	36	2.55E+1	34	8.60E+1	47	1.14E-1

Table 4-9: FLU Load Top 10 Ranks on per acre basis

FUTURE RANKS

rank	Loc. #	Coliform #/100ml-yr-ac	Loc. #	TP (lbs/yr-acre)	Loc. #	BOD (lbs/yr-acre)	Loc. #	TSS (lbs/yr-acre)	Loc. #	Zn (lbs/yr-acre)
1	8	8.81E+8	83	1.41E+0	83	6.47E+1	83	5.55E+2	83	6.50E-1
2	2	6.47E+8	82	1.21E+0	82	5.53E+1	82	4.96E+2	82	5.68E-1
3	87	6.37E+8	38	1.01E+0	22	4.31E+1	57	3.32E+2	57	3.41E-1
4	4	6.33E+8	30	9.64E-1	2	4.16E+1	36	2.01E+2	8	2.76E-1
5	80	6.06E+8	47	9.62E-1	30	4.16E+1	8	2.00E+2	2	2.49E-1
6	5	6.05E+8	49	8.87E-1	87	4.11E+1	56	1.64E+2	22	2.44E-1
7	22	6.01E+8	36	8.80E-1	41	4.10E+1	22	1.59E+2	87	2.44E-1
8	7	5.98E+8	70	8.42E-1	42	4.09E+1	2	1.54E+2	80	2.43E-1
9	41	5.89E+8	22	8.10E-1	80	4.03E+1	87	1.52E+2	41	2.42E-1
10	42	5.84E+8	48	7.97E-1	81	4.01E+1	41	1.51E+2	4	2.35E-1

Another important indicator of a catchment's pollution was its pollutant loading per acre. Pollutant loading was normalized by the size of the catchment to better emphasize areas where the land was contributing a high concentration of pollution. The normalized pollutant loading values were determined by dividing each catchment's pollutant loadings by its area. These results were included alongside the other pollutant loading results in Appendix 3. Tables 3D-3, 5, 7, 13, 15, 17, and 18 show normalized pollutant loading information. Additionally, Tables 4-8 and 4-9 list the catchments with the ten highest values for each pollutant on a per acre basis.

The ten figures in Appendix 3-B are maps that show the catchments ranked by their level of pollutant contribution to the Okatie River. The first five figures show annual pollutant loading amounts per acre for each catchment. These results were normalized as explained above. Figures 5 through 10 in Appendix 3-B display annual pollutant loads for each catchment as a whole and are not normalized with respect to catchment area. Each of the ten figures ranks the catchments in the watershed based on their contribution of a single pollutant. In each figure, catchments are shaded a color on a standard dark red to white to dark blue color gradient based on their level of pollutant loading. The catchment with the highest load for a given pollutant appears the darkest red on the figure representing that pollutant. Catchments are colored increasingly white and then blue as their pollutant loads decrease. The catchment with the lowest pollutant load for a given pollutant then appears the darkest blue on the figure for that pollutant. For each figure, a catchment has a color that represents its contribution of a given pollutant relative to the other catchments' contribution of the same pollutant. The units and range of catchment pollutant loading values are different for each pollutant, and therefore, for each figure. The use of a standard color gradient across figures allow for quick comparison of where the high, low and medium contributors are for all of the pollutants. However, because identical colors on separate figures may represent different pollutant loading units and ranges of values, always refer to the legend to ensure that similar information is being compared in a proper and meaningful way.

Analysis of pollutant loading under PLU conditions yielded the following observations:

- The areas of highest loading were spatially similar for all of the five pollutants.
- High and low pollutant areas tended to be formed by several adjacent catchments suggesting regional land use patterns affect pollutant loading.
- Areas throughout the north, in the east, south, and southwest, where PLU (see Figure 1-7) is AG and/or residential (LDR and MDR) tended to have the highest relative pollutant loads.
- The non-normalized pollutant loading figures show, with several exceptions, that the larger catchments tended to contribute greater pollutant loads.
- Normalization shifted some of highest pollutant loading values off of the largest catchments and onto smaller ones. However, some of the larger catchments contributed higher loads/acre as well.
- Under PLU conditions, the larger catchments contributed both high total loads and high loads per acre. This is probably due, in some part, to the presence of agriculture and residential land use on the catchments.

The ten figures in Appendix 3-B are maps that show the catchments ranked by their level of pollutant contribution to the Okatie River. The first five figures show annual pollutant loading amounts per acre for each catchment. These results were normalized as explained above. Figures 5 through 10 display annual pollutant loads for each catchment as a whole and are not normalized with respect to catchment area. As with the maps in 3-A, the catchments in these figures with high pollutant loading appear dark red and grade to catchments with low pollution levels displayed as a dark blue.

Analysis of pollutant loading under FLU conditions yielded the following observations:

- The areas of highest loading were spatially similar for all of the five pollutants.
- High and low pollutant areas tended to be formed by several adjacent catchments suggesting regional land use patterns affect pollutant loading.
- Areas on the west, northwest, south, and southwest, where FLU (see Figure 1-8) is COM, tended to have the highest relative pollutant loads.
- The non-normalized pollutant loading figures show, with several exceptions, that the larger catchments tended to contribute greater pollutant loads.
- Larger catchments often contributed greater total pollutant loads, but lesser loads per acre.
- When pollutant loading was viewed on a per acre basis, the relationship between commercial land use and high pollutant loads was emphasized.

The model predicted that alterations in FLU would produce changes in each catchment's pollutant contribution to the Okatie River. These predictions were expressed in two forms below. Each catchment's loads of the five pollutants (normalized by area and with BMPs in place) under PLU conditions were subtracted from the loads (normalized by area and with BMPs in place) under FLU. The resultant differences in normalized loads were thus determined and shown in tables in Appendix 3-D.   The differences were also expressed as percentages of the present pollutant loads (i.e., a value of 100% means that a catchment will double its pollutant load under FLU conditions). These values were organized in Tables 3D-17 and 3D18 and displayed spatially on thematic maps in 3-C. The catchments with the ten greatest changes, in magnitude and in percent, are shown in Table 4-10.

Analysis of changes in pollutant loading yielded the following observations:

- All of the five pollutants have had load increases in similar regions of the study area.

- High and low percent increases tended to be formed by several adjacent catchments suggesting regional land use patterns affect changes in pollutant loading.
- Pollutant loading increased the most on the outer perimeter of the study area on the western side where land use changed from its present range designation to commercial or medium density residential in the future.
- Pollutant loads also increased in catchments where light density residential changed to medium density residential.

Table 4-10: Top 10 magnitude and percent change of parameters

Rank	Loc. #	Change in Coliform (#/100ml-yr-ac)	Loc. #	Change in Coliform (#/100ml-yr-ac)	Loc. #	Change in TP (lbs/yr-acre)	Loc. #	Change in TP (lbs/yr-acre)	Loc. #	Change in BOD (lbs/yr-acre)	Loc. #	Change in BOD (lbs/yr-acre)	Loc. #	Change in TSS (lbs/yr-acre)	Loc. #	Change in TSS (lbs/yr-acre)	Loc. #	Change in Zn (lbs/yr-acre)	Loc. #	Change in Zn (lbs/yr-acre)
1	80	592420418	40	16254.074	30	0.759	67	33295.694	30	41.486	30	52957.760	42	135.156	67	79268.920	42	0.221	67	33392.016
2	42	575047749	67	11726.002	70	0.757	40	7912.794	22	39.238	67	46344.611	3	131.597	3	7708.854	87	0.217	3	5894.497
3	3	571863267	3	6859.666	67	0.745	31	3779.018	87	38.703	40	8823.505	40	127.577	92	6651.892	80	0.217	40	3820.367
4	87	533539951	42	6333.287	40	0.743	3	2475.244	80	38.118	3	5335.795	87	126.991	93	3025.437	3	0.213	92	3389.340
5	22	529217827	80	4296.386	31	0.737	92	2333.147	42	37.476	31	4005.414	80	125.413	40	2694.872	4	0.213	42	1679.693
6	84	523555774	92	2349.846	22	0.688	69	1599.417	4	37.196	92	3803.058	4	124.380	42	2174.304	22	0.212	31	1606.028
7	4	519773922	84	1496.421	87	0.670	62	1466.563	40	36.017	80	1771.422	22	117.902	94	1720.829	7	0.197	93	1280.481
8	7	480854958	31	1342.191	42	0.667	80	1310.231	3	35.736	4	1730.922	31	113.926	73	1462.204	40	0.186	4	940.771
9	1	480573731	6	1296.689	80	0.648	87	1167.087	41	35.110	87	1643.703	7	112.297	63	1435.690	5	0.185	80	848.630
10	6	448431002	93	981.317	69	0.640	68	1153.669	7	35.096	62	1641.302	93	111.406	31	1172.976	41	0.177	87	825.671

5.0 ALTERNATIVES EVALUATIONS

This section contains an evaluation of alternatives to alleviate existing and potential future flooding and water quality problems. The following guidelines were considered in evaluating the alternatives:

1. Solutions will involve the incorporation of both structural and non-structural approaches to stormwater management. The applicability of each approach is dependent upon the current state of development and future development plans for a given area.
2. Regulatory agencies should be able to accept and permit solutions.
3. Solutions should be cost-effective and affordable.
4. Solutions should seek to provide comprehensive environmental benefits. Benefits include reduced flooding, pollutant load reductions, wetland enhancement and preservation.
5. Solutions must be technically feasible, able to be implemented, and reliable. For example, infiltration based BMPs (i.e., retention ponds, exfiltration) would not be proposed for areas having poorly drained soils since they would not function properly and would promote mosquito development.

Specific water quantity problems are summarized in their corresponding sections. The following paragraphs summarize the results of the water quality evaluation and their potential impact on alternative selection.

5.1 Alternative 1

Alternative 1 involves the optimization of existing infrastructure through improved operation and maintenance for the PLU condition. In general, the major components of the stormwater management system throughout the watershed are well maintained with a few exceptions of some siltation at minor culverts. Most of the constructed stormwater management facilities are located within PUDs or are associated with new road construction. Routine maintenance practices include removal of trash and debris and mowing and removal of excess vegetation.

The siltation observed in the culverts associated with the State Road 170 construction is expected to be removed at the conclusion of construction activities. The simulations were performed assuming that the culverts were clear. The one flooding problem associated with an inadequately maintained culvert (Problem Area 10) is located in a remote area currently in silviculture. As stated in the Buckwalter Tract Drainage Study, this culvert will be upgraded as part of future development activities. Therefore, no additional modifications to the input data sets were required.

5.2 Regional Facilities

In preparation for evaluating structural alternatives for Alternatives 2 and 3, candidate properties in the watershed were evaluated for their potential use as a regional stormwater facility to serve both water quantity and water quality needs. Four regional sub-watershed areas (Okatie West tributary, Okatie East tributary (Buckwalter), Oldfield, and Cherry Point) were preliminarily selected based on topographical relief from USGS maps, surface runoff drainage paths, and water quality parameters. A total of eight properties make up the four sub-watershed areas (see Figure 5-1). These properties are outlined and information was summarized using Beaufort County property ArcView GIS information and the Property Information Module at http://maps.co.beaufort.sc.us/isa/Parcels/default.htm. The property sizes ranged from 9.8 acres to 125 acres in size, for a total of 389.3 acres. Ownership and appraisal values are shown in the appendices. Appraised market values range between $6,000 and $11,000 per acre with an average value of $9,000 per acre for the five known property values. Undeveloped land values of $6,500/acre were used if there were no available appraisal values. Table 5-1 summarizes rough estimate costs for purchasing, design, excavation, and planting of a wet detention pond with a mean depth of five feet.

Properties 3, 4, 5, and 6 have aerial photo-interpreted and USGS topographical information that demark drainage ditches. These ditches were likely excavated a number of years ago. Amongst many other drainage ditches in the Okatie basin, these were put in place to drain wetlands and to provide for more upland sites for other anthropogenic uses such as silviculture. This function is a water quantity verses water quality issue that may now be used for mitigation of other impacts by obtaining conservation easements and by plugging the ditches at strategic locations. This would act to restore the hydrology of these properties and therefore likely improve water quality by detaining storm event flows that would normally quickly flush into the Okatie estuarine system.

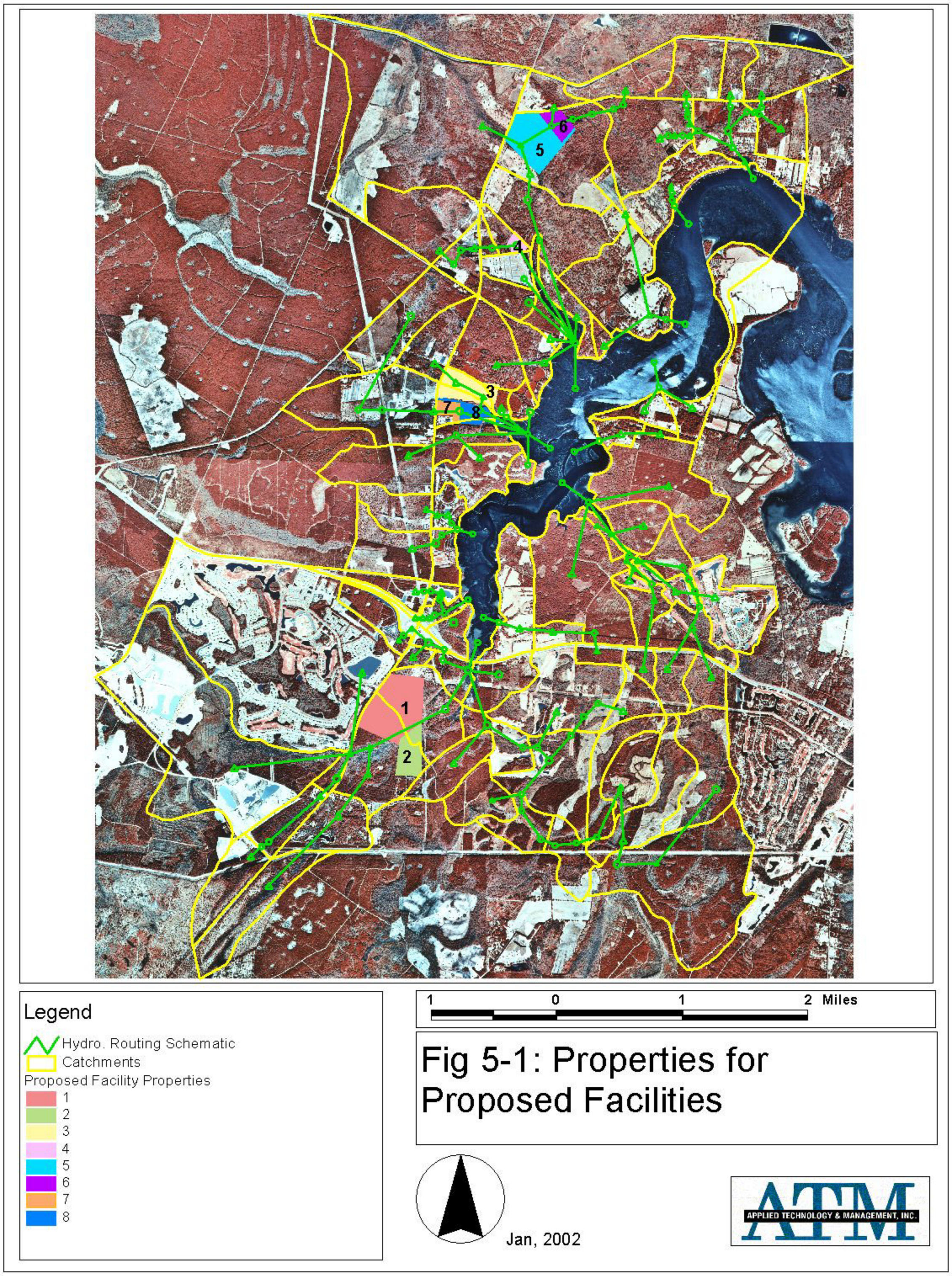


Fig 5-1: Properties for Proposed Facilities

Table 5-1 Regional Facilities											
	Total Area	Useable Area	Detention Pond Area	Volume Excavation	Excavation Cost	Appraised Market Val.	Structural Costs	Planting Costs	Design Costs	Total Costs	Costs per acre detention
site	(acres)	(acres)	(acres)	(acre-ft)	($)	($)	($)	($)	($)	($)	pond ($)
1	125.00	120.00	90.00	450.00	1,815,000	1,375,000	49,500	21,709	273,500	3,534,709	39,275
2	42.00	28.00	21.00	26.25	105,875	**273,000**	11,550	10,486	18,547	419,459	19,974
3	72.00	70.00	52.50	262.50	1,058,750	630,000	28,875	16,581	160,110	1,894,315	36,082
4	9.80	9.80	7.35	36.75	148,225	**63,700**	5,000	6,204	23,117	246,246	33,503
5	77.50	75.00	56.25	281.25	1,134,375	713,000	30,938	17,163	171,459	2,066,934	36,745
6	23.80	23.80	17.85	89.25	359,975	**154,700**	9,818	9,668	55,022	589,182	33,007
7	13.09	12.00	9.00	45.00	181,500	78,500	5,000	6,865	28,038	299,903	33,323
8	26.08	15.00	11.25	56.25	226,875	216,700	6,188	7,675	34,907	492,345	43,764
Sum	389.27	353.60	265.20		5,030,575	3,504,600	146,868	96,351	764,700	9,543,094	*34,459 Average*

Table 5-1 estimates are based on the following cost assumptions:

Excavation cost	$	2.50	*per yd^3*	Provides for final grading
Market value	$	6,500.00	*per acre*	For appraised values **in bold** where property appraiser information was unavailable
Structural costs	$	550.00	*per acre*	For estimated cost due to materials and installation of stormwater control and conveyance structures - $ 5,000.00 minimum
Planting costs	$	2.50	*per plant*	Based on plant spacing of 3' OC - 3 plants/ 3lf or perimeter
	$	350.00	*per acre*	Based on grassing (seed) and a perimeter width of 30 feet
Design costs		14.500%		Based on percentage times the sum of construction, structural and planting costs Includes estimated surveying, site layout, permitting and engineering design fees

In addition to stormwater detention facilities, many of these properties also contain land suitable for 100-ft riparian buffer zones (see Figure 6-3 for property and buffer locations, see Section 6.1.1 for an in-depth discussion of buffer zones). In some cases, buffers may be worth implementing in the facilities developed on these sites. Implementation of buffer zones would be a largely non-structural means of augmenting the stormwater treatment capabilities on the properties. Buffer zones reduce pollutant loading generated by preventing, trapping, and filtering pollution in stormwater runoff from the contributing area around them. Buffers zones on three of the properties would treat runoff from catchments with medium to high loading of certain pollutants. With buffer zones, the natural riparian system surrounding rivers and streams serves as a barrier to, and filter for, non point source pollution from runoff. If a natural riparian system is already present on the properties then implementing it might entail only minor maintenance and vegetation management. If the areas to be used as buffer zones are highly altered, though, more restoration work might be involved.

5.3 Alternative 2

Alternative 2 involves the implementation of structural and non-structural modifications to the stormwater management system under the PLU condition. In the evaluation and selection of alternatives to correct water quantity and water quality problems, topography and soil conditions are major factors in determining which types of BMPs are implemented and functional in a particular situation. For example, BMPs that rely on infiltration would not be good practices for areas that contain marginal soils such as A/D, B/D, or D classes (refer to Section 1.4.5 for descriptions). The following sections describe locations of water quantity and water quality problems, proposed structural and non-structural modifications to alleviate flooding and improve water quality treatment, and simulation results as necessary.

The results of the water quantity evaluations indicate that flooding problems occur almost exclusively within undeveloped areas. This is an indication that the state and county standards for peak flow attenuation and flood protection are adequate. Recommendations were listed in order of priority for construction based on the severity of the problem, the property damage and loss-of-life potential, and costs.

The potential water quality problem areas for the PLU were described in Section 4. These areas include the Okatie West tributary, which is in the headwaters of the Okatie River. In order to provide additional protection to these sensitive headwaters and to augment the existing stormwater management system's treatment capabilities, a regional facility is proposed and is identified in Figure 5-2 as Regional Facility Properties 1 and 2.

Regional Facilities Property 1

Property 1 is the largest contiguous property of 125 acres, but has the highest cost per acre at $11,000 compared to the average value of $9,000 (see Table 5-1). The current land use is primarily a silviculture operation (see Figure 5-2). This regional facility could be used to polish the stormwater effluent from Sun City PUD just to the west. Additionally these headwaters to the Okatie are just upstream of the only restricted shellfish station, 18-08.

Regional Facilities Property 2

Property 2 totals 42 acres although approximately only 28 acres would be able to be utilized for a stormwater BMP (see Table 5-1). Appraisal information was not available so an expected unimproved land value of $6,500 was used. The current land use is unknown but appears to be a borrow pit operation as there are several small ponds on the property (see Figure 5-2). This would make earth-moving costs minimal, as there would likely be no site soil removal. Table 5-1 determination of the excavation costs factors this in by quartering the excavation volume. This regional facility could be used to polish the stormwater effluent from the future Buckwalter that is in its planning stages. Additionally these headwaters to the Okatie are just upstream of the only restricted shellfish station, 18-08.

Facilities at the Sites 1 and 2 would treat Catchments 56 and 74. These are the first and third largest catchments in the watershed. They have some of the highest un-normalized pollutant loads (within the top 5 for all five pollutants) in the study area for both PLU and FLU conditions. Facilities at this site will treat these hotspots. The facilities would also treat Catchments 61, 62 and 77. Catchment 61 has high un-normalized FC loading. These catchments have a 180% - 1400% range of increase in pollutant loading for the five pollutants under future commercial and medium density land use designations. Facilities at Sites 1 and 2 will treat this area of potentially increasing development and pollutant loading.

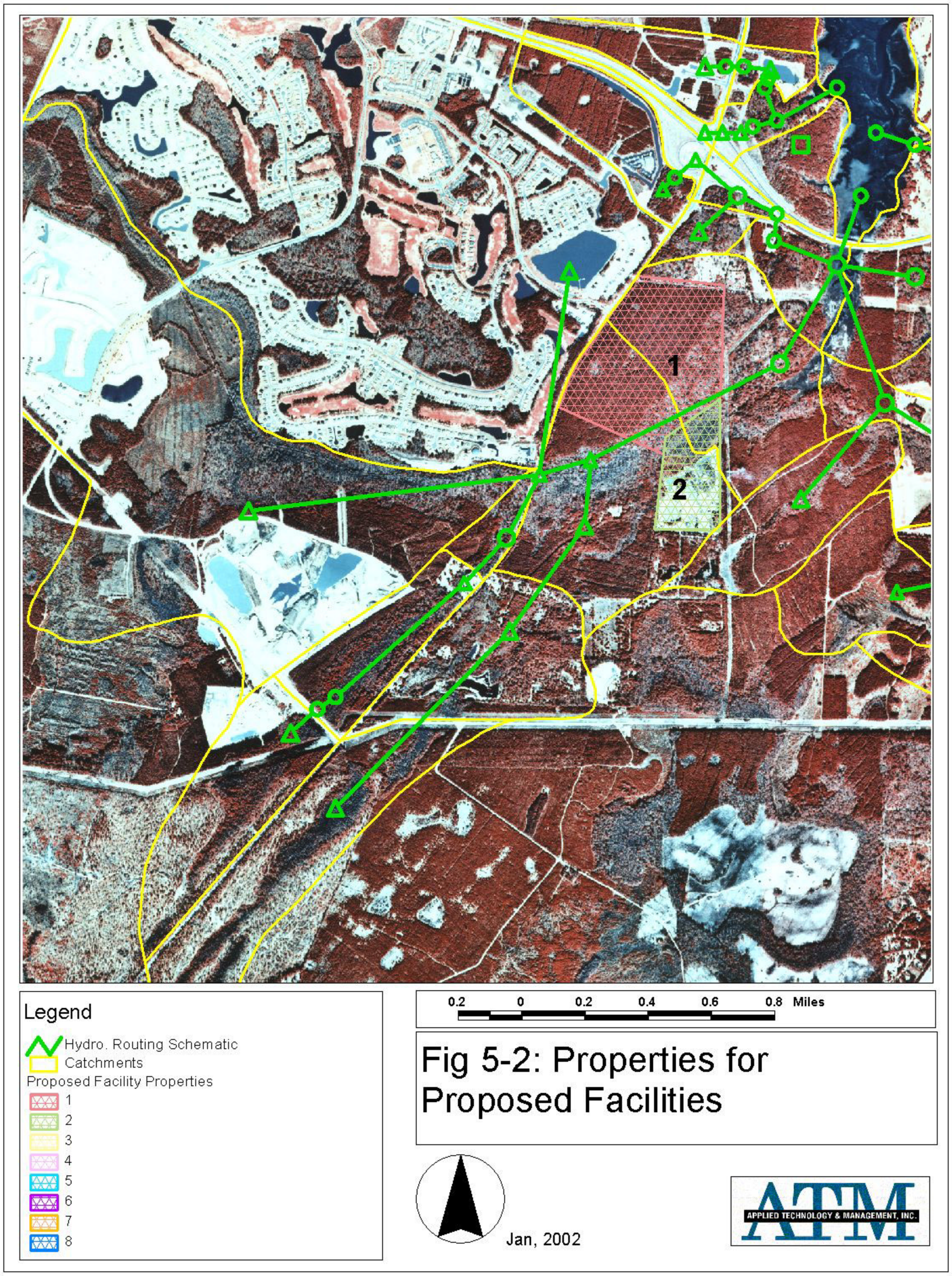


Fig 5-2: Properties for Proposed Facilities

Properties 1 and 2 lay partially on headwaters wetlands in Catchments 61 and 59 (see Figures 5-1, 5-3, and 6-3). A portion of the land on both properties is suitable for buffer zones. If the design of facilities on these properties included buffer zones on suitable lands or an equivalent BMP then stormwater pollution to the wetlands could be greatly reduced at these sites and slightly reduced in Catchments 61 and 59. Buffer modeling results show that if 100-ft buffers were put in place, pollutant loads under FLU conditions from Catchment 61 would be reduced by 3-5%. They would be reduced by 2-3% on Catchment 59. Although these are small percent reductions, Catchment 61 has high FC loading and a small percentage reduction might yield a notable total FC load reduction. Additionally, these reductions may be achieved at little additional cost if the properties already contain a natural riparian system within the buffer zones, or if the design of the facilities on these properties provides equivalent treatment of runoff.

5.4 Alternatives 3 and 4

Alternative 3 involves implementation of structural and non-structural requirements to alleviate flooding and water quality problems under the FLU condition. Given this track record, it is reasonable future development will not create additional flooding problems. Because the developments occurring in the area are PUDs and, as such, are evaluated in somewhat of a basin approach, current peak flow attenuation and flood protection regulations should be adequate to provide for future development activities.

The potential water quality problem areas occurring in the FLU scenario is largely the result of commercial development along State Road 170, in Jasper County. These areas are presented in Figure 1-8. Water quality treatment requirements in Jasper County are based on SCDHEC standards, which are generally less rigorous than the water quality treatment requirements in Beaufort County. Two approaches to improving the treatment requirements are through non-structural means, such as raising treatment requirements for new development in Jasper County, or by constructing a regional facility that would increase pollutant removal efficiencies for the contributing area. The approach of improving treatment requirements in Jasper County will be discussed more fully in Section 6. The use of regional facilities to increase removal efficiencies will be discussed here.

Regional Facilities Property 3

Property 3 totals 72 acres with approximately 70 that could be improved upon for a stormwater BMP (see Table 5-1). Appraisal information estimates the cost per acre at

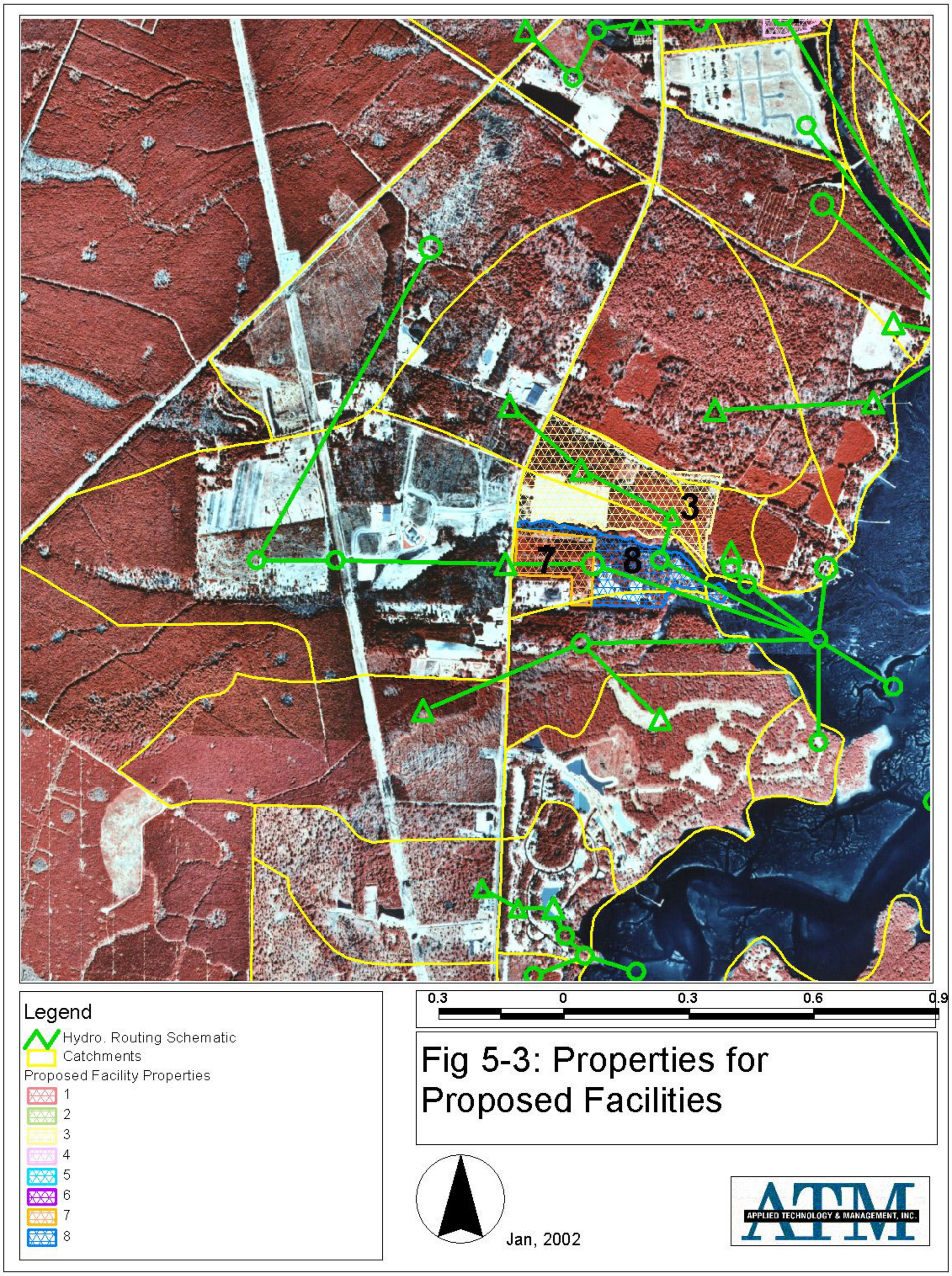


Fig 5-3: Properties for Proposed Facilities

$8,750/acre, which is slightly below the average cost of the five land appraisals. The current land use is approximately 60% forested and 40% cleared with a small structure on it (see Figure 5-3). Additionally there is a drainage ditch running through the property. This regional facility could be used to polish the stormwater effluent from Catchments 23 and 26.

Catchment 23 has a high level of FC loading for FLU. Normalized FC loading is very high, and un-normalized FC loading is relatively high. This catchment has relatively high levels of FC in PLU conditions as well. The catchment also has a high percentage increase in FC, TP, and BOD between PLU and FLU. Catchment 26 has relatively low pollutant loading in all circumstances. It also is not predicted to increase its loading very much for any pollutants. It is a smaller catchment, about 20% the size of Catchment 23. The facility at Site 3 would treat Catchment 23 and would therefore address this high source of FC/acre and medium total source of FC.

Sites 3, 7 and 8 are all in close proximity to the Okatie River and all border a large tributary to it. A sizeable portion of these properties contain land suitable for buffers (see Figures 5-3 and 6-3). A discussion of buffer effectiveness on these properties can be found at the end of the discussion of Regional Facilities Properties 7 and 8.

Regional Facilities Property 4

Property 4 is the smallest of the proposed properties and totals 9.8 acres with the majority of the property that could be improved on for a stormwater BMP (see Table 5-1). Appraisal information was not available so the expected value of unimproved land value of $6,500 was used. The current land use is approximately 100% forested with a drainage path running through the middle of the property (see Figure 5-4).

This regional facility could be used to polish the stormwater effluent from Catchments 7, 8, 10, and 89. Catchments 7 and 8 have high levels of pollutant loading for all 5 pollutants, both normalized and un-normalized, in PLU and FLU conditions. Catchment 89 has high levels of normalized FC loading in PLU and FLU conditions. Catchment 7 has high percentage increases (400% - 1350%) for all 5 pollutants. Facilities on this site could treat pollution coming from future potential commercial development in the western fringe of the study area.

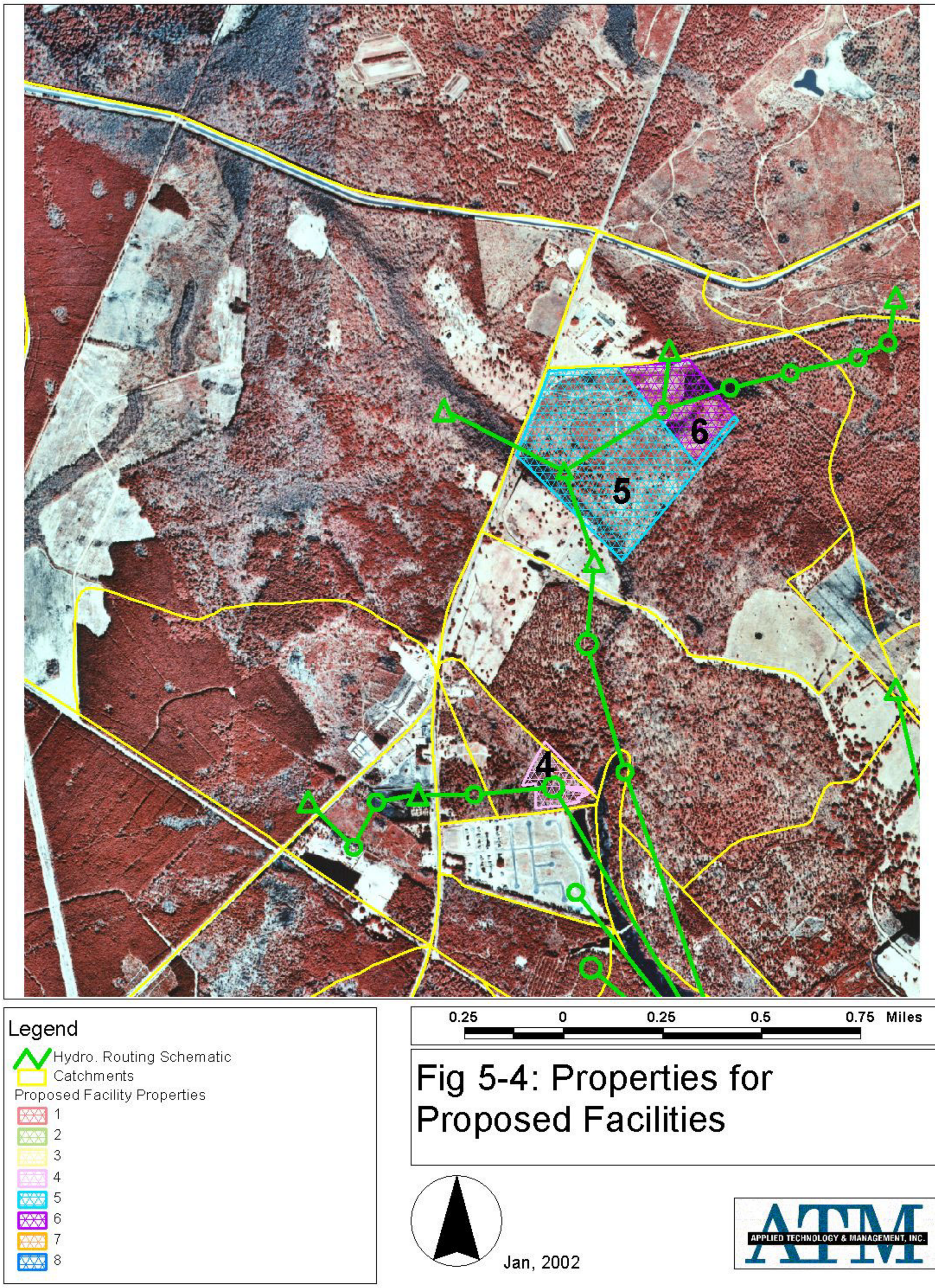


Fig 5-4: Properties for Proposed Facilities

Regional Facilities Property 5

Property 5 totals 77.5 acres with the majority of the property that could be improved upon for a stormwater BMP (see Table 5-1). Appraisal information estimates the cost per acre at $9,200/acre, which is slightly above the average cost of the five land appraisals. The current land use is approximately 100% recently cleared forested with a drainage path running through the middle of the property (see Figure 5-4 and Figure 6-2). It is apparent from comparison of the NWI classification, and the 1994 and 1999 aerial photos that the swamp slough was cleared and ditched. Additionally, a small road on the border of Properties 5 and 6 appears to impede water flow to the downstream ditch. Furthermore, the expansion of Highway 278 had cut through approximately 5.9 acres in the northwest portion of the property which was originally part of the NWI inventoried swamp wetland. This property is adjacent to Property 5 and could be used in conjunction with that property for a stormwater BMP or a hydrologic/wetland restoration as discussed in the hydrologic restoration section below. This regional facility would be used to polish the stormwater runoff from the present commercial property to the northwest and for planned FLU commercial properties.

Regional Facilities Property 6

Property 6 totals 23.8 acres with the majority of the property that could be approved upon for a stormwater BMP (see Table 5-1 and Figure 6-2). Appraisal information was not available so the expected value of undeveloped land of $6,500 was used. Additionally this property is adjacent to Property 5 and could be used in conjunction with that property. Approximately 50% of the property appears to be impacted wetlands from a hydrologic alteration. Section 6.5 provides a description of the hydrologic wetland impacts.

Facilities at the Sites 5 and 6 would treat Catchments 1-3, and 12. Catchments 1-3 have high area normalized and un-normalized (catchment total) FC loading values for FLU designations. Catchment 12 has high normalized and un-normalized FC loading values for FLU designations. Catchment 1 has a high un-normalized FC loading value, and Catchment 2 has a high normalized FC loading value for PLU designations. Catchment 2 has very high (2400% - 7700%) percentage increases in pollutant loading for FC and TP. Catchment 1 has high (200% - 590%) pollutant increase for all pollutants except TP. FC increase is especially high at 587%. Facilities on these sites could treat pollution coming from future potential commercial development in the northwestern fringe of the study area. They would not treat pollution from the residential development between this area and the Okatie River, which tends to have high TP loading for both PLU and FLU scenarios.

Site 5 contains wetlands on its southwestern side that appear to be hydrologically connected to the Okatie River (see Figures 5-1 and 5-4). It also contains land suitable for a 100-ft buffer around part of these wetlands (see Figure 6-3). If buffers were placed on all suitable lands on this property they would reduce pollutant loading from Catchment 12 by 2-4%. This property has been recommended as a candidate for hydrologic restoration (see Section 6.5). If restoration occurs, buffers around the restored areas would cover a larger contributing area in Catchment 12 and thus reduce pollutants to a higher degree. In addition, the area surrounding this property is zoned for residential use, and the property is adjacent to Okatie Highway. These areas will likely be a source of stormwater pollution. By purchasing the property and buffering the wetlands it contains, stormwater pollution from these sources can be decreased.

Regional Facilities Property 7

Property 7 totals 13.09 acres with a small residential structure that encompasses approximately 1.2 acres therefore allowing the majority of the property to be utilized for a stormwater BMP (see Table 5-1). Appraisal information estimates the cost per acre at $6,000/acre, which is the lowest cost of the five land appraisals. Additionally this property is adjacent to Property 8 and could be used in conjunction with that property. The land exclusive of the residential 1.2-acre area is predominantly a forested area (see Figure 5-3).

Regional Facilities Property 8

Property 8 totals 26.08 acres with approximately 15 useable acres for a stormwater BMP (see Table 5-1) due to a residence on the property. Appraisal information estimates the cost per acre at $8,300/acre, which is lower than the average cost of the five land appraisals. Additionally this property is adjacent to Property 7 and could be used in conjunction with that property. The land is approximately a 60% forested area and 40% cleared with a residential area (see Figure 5-3).

Facilities at Sites 7 and 8 would treat stormwater from Catchments 22, 30, 32. Catchment 32 has low pollutant loading for both PLU and FLU conditions. Catchments

22 and 30 have high normalized and total pollutant loading for all pollutants under commercially developed FLU conditions. Catchment 22 has a high (290% - 1020%) percent increase in pollutant loading for all pollutants. Catchment 30 has a high (>150%) percent increase in pollutant loading for all pollutants except FC (only 20%) and TSS (only 90%). Facilities on these sites could treat pollution coming from future potential commercial development in the western fringe of the study area.

Sites 7 and 8 are in close proximity to the Okatie River and all border a large tributary to it. Large percentages of these properties contain land suitable for buffers (see Figures 5-3 and 6-3). Buffers placed on all suitable lands in these properties would reduce stormwater pollutant loading to the Okatie River and its tributary from Catchment 32 by 28-45% (see Appendix 3, Figures 3d-1-3d-5, and Table 3d-21). Modeling results show that Catchment 32 is not a high source of pollutants, though, and the large percent reduction will not yield a large total reduction (see Appendix 3, Figures 3b-1 through 3b-10). However, because these properties are in close proximity to the Okatie River, implementation of buffers, or incorporation of some type of barrier to stormwater runoff pollution in the design of facilities on the property would curb direct pollution to it.

6.0 RECOMMENDATIONS

Based on the analyses conducted, the following recommendations are presented for implementation in the Okatie River watershed. Implementation of developed criteria and recommendations are specific to the Okatie watershed, however, many of these principles can be applied to other South Carolina coastal watersheds.

6.1 Development Review and Ordinance Modifications

Optimum design of stormwater management should mimic (and use) the features and functions of the natural ecosystem. Features including depressions, wetlands, floodplains, and vegetation provide natural infiltration, help control the velocity of runoff, extend the Tc, filter sediments and other pollutants, and recycle nutrients (Livingston, 1989).

Stormwater treatment systems should be designed for minimum maintenance by allowing the system to self-maintain and self-organize. System design should be done with the landscape as an ecotone and be based on function not form. Stormwater systems should not be over-engineered with rectangular basins, rigid structures and channels, and regular morphology as natural systems should be mimicked to accommodate biological systems (Stevens, 1999).

Stormwater systems should attempt to mimic pre-development hydrologic conditions and receiving water salinity concentrations. Most marine and many estuarine species are not well adapted to endure large fluctuations in salinity conditions. When salinity levels get below 10 ppt, many estuarine species, including oysters, cannot survive well, especially if those conditions occur frequently or for extended periods of time (Cake, 1983). Additionally, FC tend to flourish in less saline waters due to a decrease in the saline disruption of the cell membranes as described in Section 4.1. The effects of freshwater runoff are more pronounced in small drainage systems and the upper ends (headwaters) of larger drainage systems, which often receive the greatest loads of freshwater runoff compared to areas more seaward and are often larger and therefore experience less dilution than the headwater areas (SCDHEC, 2000). Stormwater pond/wetlands, regional riparian facilities, wet detention basins and modified outlet control structures increase retention of excess water from developments thus creating more stable flow and salinity conditions; however caution should be taken to not over-design these BMPs.

BMPs that utilize vegetation should use only native plants in landscaping. Ample information resources may be found such as the South Carolina Native Plant Society (www.scnativeplants.org and www.cufp.clemson.edu/scnativeplants).

6.1.1 Beaufort County Development Review Modifications

The Beaufort County Manual for Stormwater BMPs (CDM, 1998) supplies in detail the existing stormwater regulations and design criteria for BMPs. Sections 3.4.1, Overview of Structural BMPs, and 4.2.5, Recommended Approach for Beaufort County, are applicable (CDM, 1998). The listed BMPs make little mention on their ability to decrease enteric pathogens due to the small literature database and because loadings from pets and birds are not readily quantified (CDM, 1998). The following are overviews of recommended improved BMPs that should be incorporated into the county BMP manual to enhance water quality objectives inclusive of FC information.

Headwater Protection Buffers

Headwater riparian buffers are non-managed, naturally vegetated BMPs. The term "riparian" refers to the area of land along a stream, river, marsh, or shoreline. Buffers that control NPS pollution do so by two main mechanisms: deposition of solids and water infiltration. These mechanisms are a function of vegetation and soil characteristics. Riparian buffers have long been recognized for their importance in providing shade that reduces water temperature, causing deposition of sediments and other contaminants, reducing nutrient loads of streams, micro-organism and metals trapping, stabilizing stream banks with vegetation, reducing erosion caused by uncontrolled runoff, providing wildlife habitat, maintaining aquatic food webs, and providing aesthetic greenways and recreational opportunities (Cofer-Shabica, 1999; Hernandez et al., nd; FISRWG, 1998; Stevens, 1999). The width of the buffer is the most important factor in the effectiveness of this BMP and typical buffer widths are often based on economic and legal considerations rather than ecological factors. For example, to maintain local breeding bird populations of American Redstarts (*Setophaga ruticilla*) and Rufous-sided Towhees (*Pipilo erythrophythalmus*) (both of which have breeding ranges in coastal Souuth Carolina) requires a 700-foot buffer (FISRWG, 1998; Knopf, 1977).

Riparian buffers would likely act as a buffer to domestic pets in comparison to grass swales due to less accessibility for dog walking. Two recent studies independently conclude that 95% of FC found in urban stormwater was of nonhuman origin with the majority of urban FC originating from dogs. This is to be expected considering their population densities, daily defecation rate, and pathogen infection rates (CWP Concentrations, 1999). If the riparian buffer includes a hiking trail, it should be pet exclusionary or have measures to educate the public and provide a waste disposal utility such as baggies for “pooper scoopers”.

Caution should be taken in determining the minimum width of the buffer as the smaller the width of the buffer, the more concentrated wildlife will be towards the waters edge thus potentially increasing wildlife fecal contaminant levels. Compressed wildlife populations will tend to live in the remaining green spaces and will often use marsh habitat areas for defecation, using the terrestrial upland for feeding and nesting activities. For example, wildlife such as raccoons will defecate in the marsh and often become the primary source of FC bacteria in affected tidal creeks. It is important that buffer and green space design have wildlife corridors that lead away from the vegetated buffer areas adjacent to tidal creeks. This would allow and encourage wildlife feeding and defecation activities at a distance away from estuarine tidal creeks. While raccoons may still feed on oysters and defecate in the marsh, the location of alternative upland terrestrial food sources in wildlife corridors may ultimately reduce FC loadings from wildlife sources. Similar strategies may be employed for other wildlife sources such as deer, muskrat and birds (SCDHEC, 2000).

Headwater Buffer Modeling

The Okatie basin protection of important headwater areas was addressed by utilizing the model results from the future land use conditions and adjusting pollutant removal efficiencies to reflect the addition of headwater riparian buffers. Buffer width, management, available placement, and expected buffer removal efficiencies are explained below to develop expected effectiveness of the headwater protection areas.

Buffer Width

Buffer widths between 25 and 300 feet are most commonly encountered in similar environments. A 100-foot wide buffer was recommended by the Workshops on Beaufort County’s River Quality Overlay District (RQOD) ordinance (Cofer-Shabica, 1999). This was the width selected to be modeled based on the following literature reviews. A national survey of 36 local buffer programs found a range in buffer width from 20 to 200 feet on each side of the stream, with a median of 100 feet (McCutcheon, 1999).

Furthermore, 100 feet is the buffer width recommended to provide adequate stream protection (Federal Interagency Stream Restoration Working Group, 1998). Moreover, scientific research of 140 articles and books suggest that a 100-foot riparian buffer is sufficiently wide to trap sediments under most circumstances (Wegner, 1999).

Buffer Management

The workshop for Beaufort County RQOD Ordinance recommends a minimum 100-foot buffer, 50 feet of which may be “managed” (Cofer-Shabica, 1999). Their recommendation is based on modeling of 80% removal of suspended solids and does not take into account nutrients, metals or enteric pathogens (McCutcheon, 1999). The buffer width determined should be maximized for water quality protection. It is therefore recommended that the entire 100-foot buffer not be managed. Managing the 50-foot width greatly increases the possibility of water pollution due to increases in lawn maintenance (i.e., fertilization, herbicide and pesticide application), exotic species landscaping and pet excrement. The maintenance of buffers as “unmanaged” forested systems are recommended for the many secondary benefits such as wildlife habitat, maintenance of low-order streams as heterotrophic rather than autotrophic systems, maintenance of temperature and hydrologic buffers, minimization of herbicides, pesticides and fertilizers, lower maintenance and upkeep costs and increased aesthetic/recreational uses.

Buffer Placement

Modeling of the riparian buffer was highly variable as many portions of the Okatie watershed are permitted as a built-out condition due to the PUDs that are being, or have been constructed. Areas that have the potential to utilize the buffers are those that have not been constructed or permitted. These include most of Jasper County in the Okatie Basin, the Buckwalter tract, and other areas where land use is designated as agriculture range, or wetlands. Land available for buffer reaches was selected by omitting LDR, MDR, HDR, and COM land use areas, as well as permitted future land use PUDs, from land in the study area (see Figure 6-1). It is recommended that buffers be added to the county BMP manual in a timely fashion so that they can be implemented in any development imminent on buffer suitable lands.

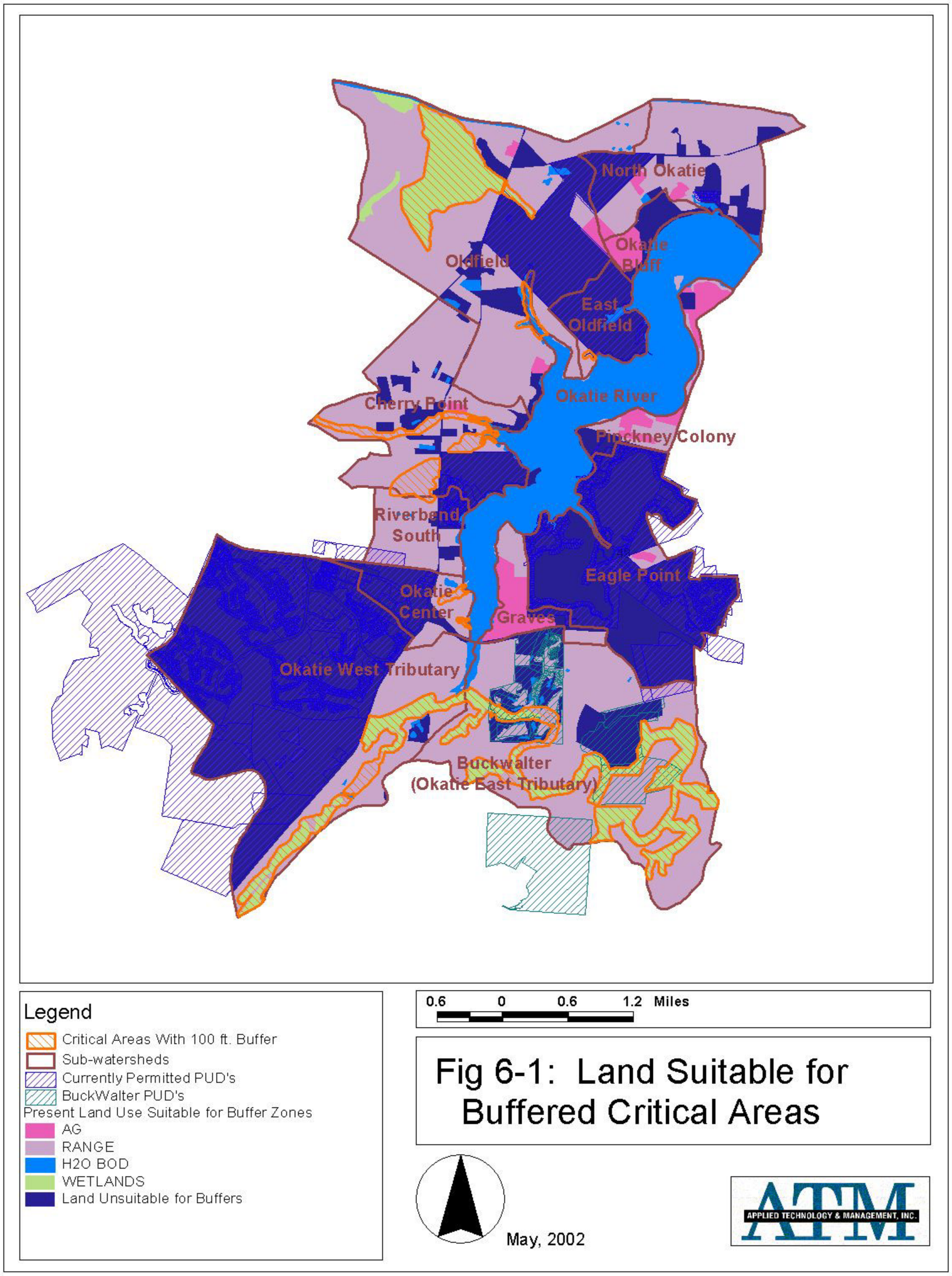


Fig 6-1: Land Suitable for Buffered Critical Areas

Buffers of 100 feet were placed around areas within available land, and likely to be considered critical areas by OCRM. This process was preformed with available spatial data in GIS. Tributaries considered critical by OCRM were defined as tributaries that began where the critical (mean high tide) lines were less then 330 ft apart and proceeded upstream to where the critical lines were less than 20 ft apart for a stream distance of over 50 ft (ROQD - Ch.4.2.5.2). OCRM also considers many wetlands east of their critical area boundary to be critical as well. In communication with Rocky Browder, the SCDHEC Regional Permitting Manager for Beaufort County, it was found that the upper critical line delineations are done on a case-by-case basis. They are reviewed every three years and are not available in any digital format. A means of approximating critical areas therefore was derived from existing spatial data.

Critical headwater areas were approximated using a combination of available spatial data. Beaufort County land use data defined water bodies and wetlands land use areas. These were the primary basis of the critical areas that were buffered. Open water land use areas that were tributaries of the Okatie River, and narrower than 330 ft, were selected to receive the 100 ft buffer. If the upstream end of these areas changed into a wetland land use, then those wetland areas were also buffered. In the absence of wetlands or open water body land use designations, hydrography, and stream data layers from Beaufort County and USGS were used in combination with a 1999 aerial photo (Figure 1-3) to approximate critical areas. All critical areas were within the study area boundaries and were east of the OCRM Critical Area Boundary as noted in Figure 6-2. Only 36 of the 95 catchments were influenced by the 100-foot buffer recommendation.

After the buffer boundaries were determined, the area of land contributing pollutants to the buffers was approximated. The contributing areas were designed as rectangular catchments 328 feet wide (100 m) as was modeled in McCutchen et al. (1999). Therefore the contributing areas include the buffer width themselves of 100 feet and the additional 228 feet of typical contributing area (see Figure 6-3). After the contributing areas were overlaid on catchment boundaries, the percent of contributing area in each catchment was determined. These percent areas were then multiplied by the expected removal efficiencies in Table 6-1 to show the percentage removal by the buffers of each of the five water pollutants in all of the catchments (see Table 3d-19 and Figures 3d-1 through 3d-5).

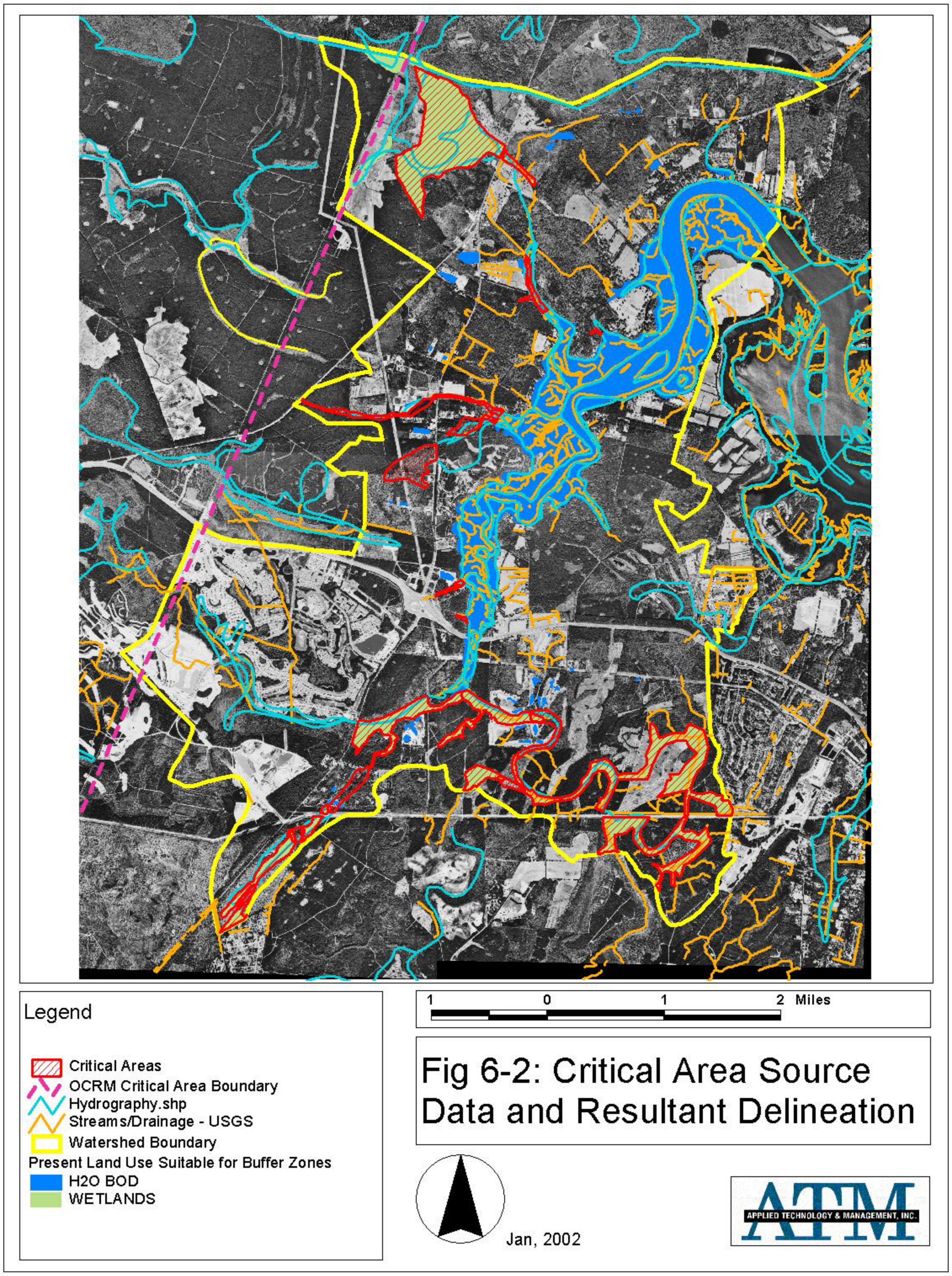


Fig 6-2: Critical Area Source Data and Resultant Delineation

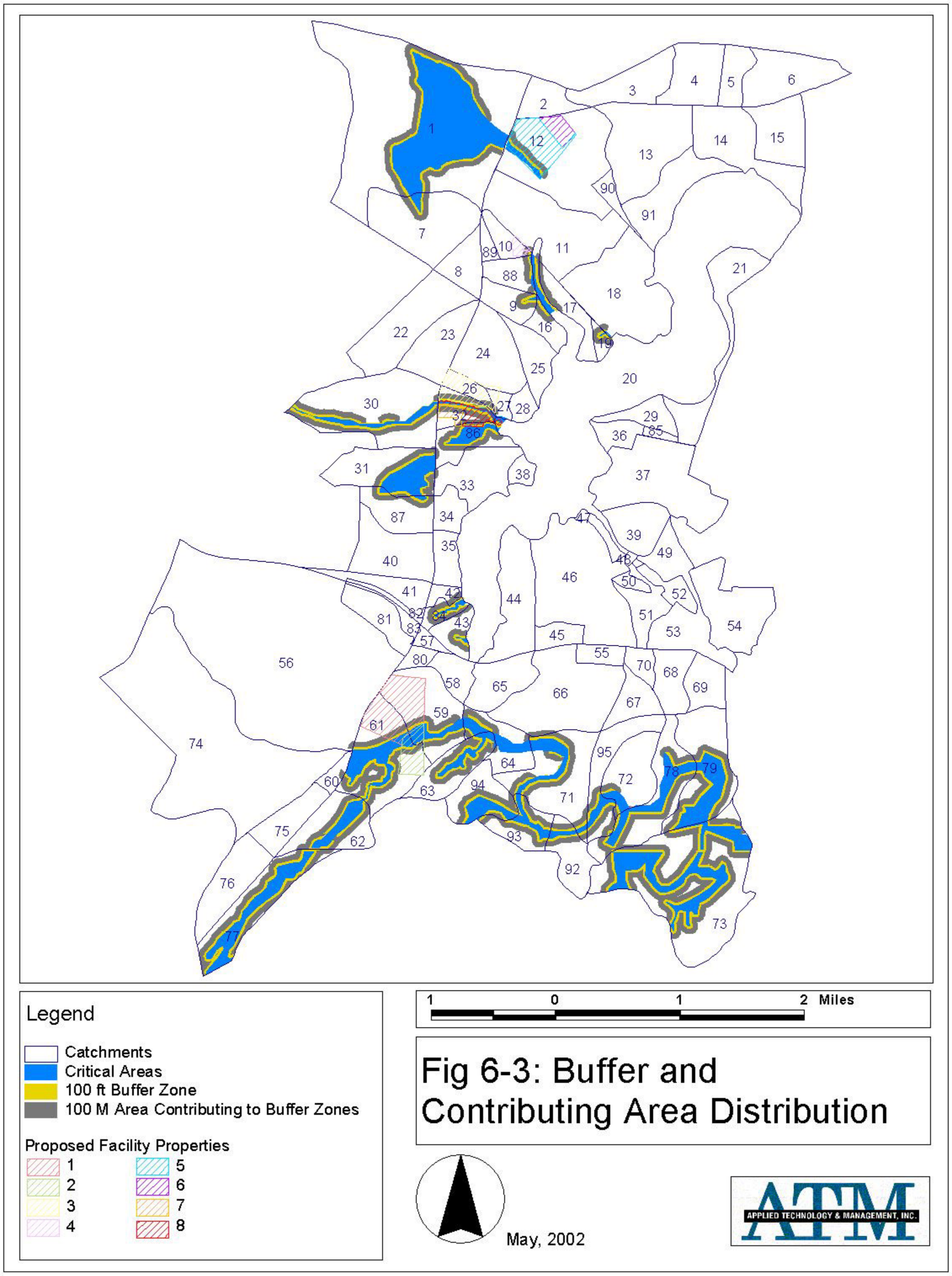


Fig 6-3: Buffer and Contributing Area Distribution

Table 6-1 Buffer Pollutant Removal Effectiveness

Pollutant Removal	Coliform	TP	BOD	TSS	Zn
Buffer reduction	50%	50%	50%	80%	60%

The PLU XPSWMM results were adjusted to FLU values by taking into account the percent area of each sub-watershed covered by the BMPs modeled (swale systems, detention ponds and riparian buffer zones). The percent reduction of pollutant parameters from buffer zones was variable and dependent on soil type, slope, vegetation coverage and humic layer, buffer width, and flow characteristics. Literature review of various vegetation management practices between maintained grass buffers or forested systems did not indicate great differences in removal efficiencies.

Additionally, existing Beaufort County ordinance buffer "vegetative strips" were not included in this analysis. The ordinance buffers call for a 20-foot single-family setback, a 30-foot buffer from impervious parking areas and a 50-foot buffer for multifamily residential, commercial and industrial construction. This ordinance calls for a minimum of a 15-foot wide buffer and may contain grasses, slatted lawn furniture, accessories and decks within the buffer. Modifications may also be granted by the county engineer (Beaufort County ordinance sec. 106-2860). These narrower buffer widths will provide some pollutant removal but not to the degree that the 100-foot-wide buffer would provide.

Pollutant Removal Efficiencies

Removal efficiencies for riparian buffers were determined from literature search. Buffer systems are highly variable and dependent on such factors as slope, soils, humic layer, vegetation, short-circuiting, and type of pollutant. Additionally, removal efficiencies typically do not include input sources from the buffer itself such as fecal deposits from native fauna. Table 6-1 provides the removal efficiencies utilized for modeling. An explanation of the literature values follows. Appendix 3, Table 3D-20 presents the FLU BMP coverage of detention ponds and grass swales with addition of with headwater protection buffers.

Nutrient reductions for 100 ft buffers were typically found to be 40 to 60% for TP and total nitrogen (TN) (Cofer-Shabica 1999). Modeling utilized the median value of 50% reduction for these two pollutants.

Sediment trapping efficiencies found in the literature were variable. An 80% pollutant reduction from trapping was chosen based on the following discussion: For infrequent runoff of once in 25 years, the minimum length of the vegetative buffers required to trap 80% of the TSS in Beaufort urban runoff was stated as 150 ft for fine sediments on a 0.2% slope, 200 feet on a 0.5% slope, and in excess of 200 feet for a 1% slope. Typical slopes in the Okatie are shallow slopes <1%. Beaufort County trapping efficiency based on the 0.2 % slope and 25-yr flow rates ranged between 75 and 90% for all soil types [McCutcheon,1999 (Figure 1)]. Because the majority of the possible buffer areas are on fine sandy loam and loamy fine sands (see Figure 1-5), with slopes generally less than 1%, expected sediment trapping efficiency for a buffer length of 100 feet would be between 80 and 90% for a 25-year storm event (see Figure 3, McCutcheon, 1999). Therefore 80% reduction in sediments should be a conservative figure.

Literature review provides case studies on FC and metals removal. A study done by Wegner (1999) reports FC reductions of 34 to 74% for a 30-foot-wide buffer and an 87% FC reduction for a 200-foot-wide buffer. Two studies found between 43 and 70% FC removal rates while two others found effectively no FC removals due to lack of sheet flow, short flow lengths and possible input from dog feces (CWP, 1999). Riparian buffers should have effective sheet flow and absorptive capability due to the leaf litter humic layer and vegetative ground cover; however, further research needs to be acquired on the effectiveness of riparian buffer zones in regards to FC removal rates. Based on these values, and grass swale information, a 50% FC reduction was modeled for the 100-ft buffer. The FC reduction value is likely a conservative value, but also does not include input sources such as wildlife contributions.

A value of 60% reduction of Zn was derived for the 100-ft buffer from the information in the Wegner (1999) report and was modeled for Zn reduction. This value is likely conservative as metal efficiency tends to follow TSS removal rates.

The BOD reduction of 62% was reported by Wegner (1999) for a 200-ft buffer. These values were consistent with grass swale BMPs and a conservative value of 50% reduction for BOD was utilized for the 100-ft buffer.

The watershed area contributing to each buffer was derived using GIS and corresponding load reductions were calculated. These results were then integrated into the FLU load reduction calculations. The removal efficiencies of the buffers are listed on table “FLU buffer reduction” (see Appendix 3, Table 3d-19). The buffer load reduction values were combined with the load reductions from the other BMPs (detention ponds, swales) to derive the total removal efficiencies expected for FLU conditions with all BMPs in place (see Appendix 3, Table 3d-19). These data were also mapped to spatial data layers illustrating the expected percent removal of FC, BOD, TSS, Zn and TP in each of the catchments (see Appendix 3, Figures 3d-1 through 3d-4). Note that no catchment was allowed to have over 100% of its area covered by BMPs.

The results of the buffer modeling and the removal efficiency calculations show that there are several places in the watershed that are where buffer implementation is possible under current land use restrictions. In these places buffers may remove 50 - 80% of pollutants coming from their contributing areas (see Table 6-1). The amount of pollution generated in the contributing areas determines the total pollutant load reduction that each buffer zone will offer.

Buffers implemented as BMPs for new development will probably have contributing areas that generate a notable amount of pollution. The water quality modeling performed in this study shows that pollutant loading tends to increase when land is developed for residential or commercial uses. Buffers put in with new developments will have these developments in their contributing areas. The buffers will thus reduce the pollution coming from these high loading sources. Implementation of buffers by new developments will also complement hydrologic restoration efforts discussed in Section 6.5. Buffers would provide an additional barrier to pollutants entering these restored areas from residential development that will be surrounding them.

Wet Detention Ponds

Wet detention ponds have been proven effective in reducing BOD, TSS, and heavy metal concentrations in runoff from urban areas and in reducing peak runoff rates; however design criteria, and operation and maintenance may be improved upon to increase pollutant removal efficiency and may not be recommended as a BMP for FC removal.

Wet detention systems are designed to hold stormwater and release it gradually to the outfall (see above on salinity fluctuation). One of the major treatment mechanisms is sedimentation, leading to removal of suspended solids. Removal rates are reported to be 80 to 90% for TSS, 70 to 80% for Pb, 40 to 50% for Zn, and 20 to 40% for BOD. These components are likely associated with particulates that are removed by sedimentation (Borden et al., 1997).

Another approach to pollutant removal is in viewing the detention pond as a lake with a controlled level of eutrophication, thereby accounting for biological, physical, and chemical assimilation of stormwater pollutants in addition to the sedimentation removal mechanism (WEF/ASCE, 1992).

There are three vital criteria in determining how efficiently the wet detention ponds work. First, the volume of the permanent pool should be designed to provide 2-4 weeks of detention time so algae can grow. This is based on a theory of operation by Hartigan employing controlled eutrophication (ASCE, 1998). Phytoplankton and periphyton are beneficial to water quality as they uptake soluble nutrients, metal ions, and bio-uptake hydrocarbons. Second, the depth of the permanent pool should be greater than 4-6 feet but shallower than 10-15 feet so water remains wind mixed and the bottom sediment stays aerobic. If the bottom sediments turn anaerobic, it will release nutrients in the overlying pool and be washed out in the next rainstorm. Third, a shallow littoral zone should be established to allow the aquatic plants within this zone to provide biological assimilation of dissolved stormwater pollutants. The littoral zone should cover at least 30% of the ponds surface area and have a gentle slope greater than 6:1 to a depth of two feet below the control elevation (WEF/ASCE, 1992).

FC counts can also be substantially reduced by sedimentation or die-off but removal rates for detention ponds are widely variable. It should be noted that influent water quality has a major impact on pond removal efficiency as both total mass removed and as a percentage of the influent load (CWP, 1999). Typically a very high (hypereutrophic) loading will result in higher percentage and mass removal of a given pollutant in comparison to a mesotrophic system. For example, the hypereutrophic pond in a North Carolina study removed between 70 to 90%, whereas the moderately loaded pond had a negligible effect on FC concentrations (Borden et al., 1997). A mean FC removal efficiency was about 65% (range -5 to 98%) from a study of 10 ponds (CWP, 1999).

The Eagle Point Water Quality Report illustrates the highly variable efficiency in regards to FC removal in the Okatie Basin. In two different sample sets (20 Oct. 97 and 14 Oct. 99), respective input/output FC values were 2/380 MPN and 56/1100 MPN (Lopez, 2000). Two other wet pond systems studied in the Piedmont Region of North Carolina also had FC removal efficiencies between –2028 and 97.7% and –844 and 96% (Borden et al., 1997).

Additionally, wet detention ponds may function as a FC source rather than a sink in regards to design parameters. A pre-development condition of an allochthonous (main energy source coming from outside the channel) forested stream in a dynamic-equilibrium balanced system will act as a different type of ecosystem than a post-development ponded autochthonous (main energy source within the water body) system. This type of created autotrophic system may also provide different habitat for bird species (such as ducks, geese, and egrets) and possibly support roosting grounds, which may provide higher incidence of FC counts from their guano. Ducks for example have a higher density (33,000,000#/gram) of FC per gram of feces than humans, cats, dogs, cows, pigs, chicken and turkey (Kadlec and Knight, 1996). Investigating the effects of ducks in another manner, Metcalf and Eddy (1991) report ducks having FC per capita generation rates of 11×10^9 which is more than humans (2×10^9), chicken, cow, pigs, and turkey. This would equate to having one duck contribute 891 FC/100 mL in a 1 acre-ft volume of water. Consideration therefore should be warranted in wet detention pond design to minimize the utilization of the bird family Anatidae (ducks) from utilizing these storm water systems.

The county regulations recommend that areas with soils classified as C, D, A/D, B/D and C/D utilize detention basins as their BMP. County design criteria require that the pond be designed so that the post-development peak flow rate is less than or equal to the pre-development flow rate for the 25-year, 24-hr design storm which is more stringent then the state requirement (CDM, 1998). Because approximately 97% of the Okatie watershed falls into this category, this has been the most widely utilized BMP in the area.

The Beaufort County BMP Manual makes no reference to littoral zone coverage although it calls for a 10-ft littoral zone. If a wet detention pond is to be utilized as the BMP of choice, a 30% pond littoral zone area should be incorporated.

Additionally, the Beaufort County BMP Manual has guidelines for a 10-ft safety bench but has no details of this safety bench. It is recommended that this safety bench be used as a buffer strip with no mowing activity to prevent grass clippings (nutrient source) from entering the pond system and to allow for other buffer mechanisms to improve water quality in the pond system. Some high nutrient stormwater ponds such as those found on golf courses may warrant extra water quality mechanisms such as aerators to prevent anaerobic re-suspension of nutrients from occurring.

Stormwater Pond/Wetlands

Wetland systems would have hydrologic design parameters similar to wet detention ponds. Several design factors would be incorporated in wetland systems to include a larger percentage (>50%) of littoral wetland fringe at the inflow and outfall settling basins, directed sheet flow through 100% native aquatic macrophytic vegetation, shallow slopes (~10:1), and berms to redirect flow and prevent short-circuiting.

The pond/wetland system removes pollutants through a number of physical, chemical and biological mechanisms. As with detention ponds, sedimentation is the dominant removal mechanism however the increased capacity for water quality treatment is augmented by the complex interactions of the wetland community. Plant and root networks reduce velocities and help prevent re-suspension. In addition, adsorption to sediments and plants plays an important role in removal of phosphorous, trace metal, and some hydrocarbons. The plankton community that resides amongst wetland systems also predate on bacterial populations (CWP, 1999). Wetland plants themselves can provide some physical filtration as well as take up nutrients. The wetlands environment also provides excellent conditions for microbial removal of nitrogen and organic matter.

Ponds with wetlands perform better than ponds without wetlands despite a decline in wetland performance during the non-growing season. Projected long-term removal rates are 75% for TSS, 65% for TP, 40% for TN, 15% for TOC, 75% for lead, 50% for Zn, and a 2-log unit reduction in bacteria (Schueler, 1992). These estimates are consistent with an 87% TSS removal efficiency reported for stormwater wetlands (WEF/ASCE, 1998). It is difficult to compare removal efficiencies between wetlands due to the lack of a standard set of design criteria (WEF/ASCE, 1998).

Wetland systems may be advantageous over wet pond systems in that the higher vegetative cover may not be suitable habitat for the Anatidae family as described in the wet detention pond system and thus minimizing the fecal source of FC. This may be done by reducing turf and open water areas around the system (CWP, 1999). Additionally, the incorporation of wetlands into a comprehensive stormwater management system achieves several additional objectives, including reduced operation/maintenance, wetland preservation and revitalization (UWRRC/WEF, 1992). Native plant landscaping in the wetlands may provide additional aesthetics and provide refuges for wild fauna.

Dry Retention Ponds

It is noted that Harper found the most effective stormwater systems were dry retention systems (Harper, 1995). Where soils allow for implementation of this BMP (HSG A or B) these should be required particularly in headwater areas, for FC removal and maintenance of freshwater flow regimes.

Baffle Box Systems

These hard engineering practices are typically based on a concrete modular structures that are placed in–line with the given drainage system. They must be routinely maintained and cleaned out with a suction pump apparatus typically every 6 months to a year. There are several companies that promote similar products such as Continuous Deflective Separation Systems© (CDS technology) and The Storm Treat System©, Stormceptor®, multi-chamber treatment train, and conventional baffle box systems such as those in place by the Indian River Lagoon National Estuary Program.

Results vary as the Indian River Lagoon system has high sediment removal rates but low nutrient or FC removal (www.epa.gov/owow/estuaries/coastlines/jun00/indianrivnep.html) whereas a report for the StormTreat System© claims 97% FC, 99% TSS and a 89% phosphorus removal for one system in Kingston, MA, from 5 sample events (Horsley, 1995). Similarly a CDS report (Wong et al., 1999) states that tests have indicated near 100% trapping efficiency for solids sizes down to 40% of the minimum aperture size of the separation screen yet the same in-situ CDS sampling results in Florida show a more realistic removal efficiency of 52% TSS and 31% phosphorus (Strynchuk et al., 1997). The Stormceptor® is projected to have a 75% removal rate of TSS (Stormtreat©, 1997) however other studies showed TSS removal rates of 21% and 51.5% (CWP, 1999, TN 104) illustrating possible biased data. Additionally, the Madison study found that less than 5 percent of the trapped sediment in the tank was of silt or clay.

Of the baffle technologies reviewed, the StormTreat System©, seems most applicable in the realm of FC reduction due to its incorporation of a small subsurface treatment wetland around its periphery. Baffle technologies should be used when there are few alternatives due to aerial constraints and are best targeted to settle-able solids and the associated pollutants.

Infiltration/Sand Filtration

These systems require a pre-treatment primary sedimentation system of which either dry or wet detention systems are typically used. A weir system diverts the first ½ inch to 1 inch of a rain event to be filtered. During large storm events the water is bypassed downstream.

Typically, a rock gravel bottom is overlain with a clean sand layer that allows the secondary water to flow through the media. These systems require a minimum of two to three feet of head differential for gravity drainage. Recent developments have "sandwiched" peat layers in between the underlying sand for varying treatment results. Land requirements are typically 100 to 400 square foot per impervious acre (Schueler, 2000a).

Treatment costs are typically between $10,000 and $20,000/impervious acre which may be 5 to 10 times more expensive than conventional treatment systems. These systems are more cost effective for larger treatment areas; however they are recommended for smaller development sites (Schueler, 2000a).

A maintenance program is required to inspect the sand layer for clogging and the upper few inches of sand must be replaced every few years. The old sand must be discarded typically in a landfill.

Water quality reports vary in regards to FC removal efficiencies. A sand filtration study in the early 1990s in Austin, Texas reported between 36 and 83% removal of FC (Schueler, 2000a); whereas a mean FC removal efficiency was reported at 50% for nine sand filters in Texas (CWP, 1999). An implemented case study in Orleans, Massachusetts installed four subsurface soil infiltration systems and a surface sand filter specifically for shellfish bed closures from NPS fecal contamination runoff (Bingham et al., 1996). Water quality results have not been reported. These systems should be considered in conjunction with pre-existing detention or retention basins that have sub-par FC concentrations.

Schueler (2000b) recommends extending pre-treatment systems to an increased retention time of 40 hours combined with a finer grained sand layer within the filter media.

In-situ soil filtration systems are not recommended because of the highly impervious Class D soils in the Okatie drainage basin; however infiltration should be maximized whenever possible.

Imperviousness

The higher percentage of imperviousness, the higher the value of peak flows from runoff events and pollutant flushing to the Okatie. Several studies have shown that around a 10% imperviousness results in degraded water quality (Cofer-Shabica, 1999). The recommendation of 7.5% imperviousness should be adopted through impervious surface reduction and BMPs to minimize water quality degradation.

Grass Swales/Biofiltration Swales and Filter Strips

A swale is a channel similar to, but wider than a ditch that is designed only for transporting peak flows. Small check dams (6 to 12” in height) may be placed perpendicular to flow to create micro-pools that will induce ground infiltration. Channel widths are wide to reduce stormwater runoff flow velocities and to keep the depth of flow below the vegetation under typical wet-weather conditions and to enhance filtration of sediment and particulate pollutants. The filter strips are placed along the edge of an impervious area, and designed so that sheet flow from the impervious area flows across the filter strip (CDM, 1998). These are most suitable in small residential areas with low densities and along roadsides. Nutrient removal is enhanced if the clippings are collected during mowing operations. Otherwise, it is likely best not to maintain these strips because nutrients would be released back into the water column as the cuttings decompose. Additionally, ground disturbance may further suspend sediments. Fecal contaminants may be increased in grassed swales due to dog feces. These are best used in conjunction with other BMPs. Minimization of directly connected impervious areas (DCIA) by restricting the use of standard curb and gutter should also be encouraged and directed into the grass swales.

County standards presented in Section 5.4.3 of the ordinance for water quality control state that "the first flush runoff (0.5 -1.0 inch) from paved streets and parking areas may be detrimental to maintenance of water quality standards. Therefore the filtering of runoff from streets and parking areas through vegetation, grass, gravel, sand or other filter mediums to remove oil, grease, gasoline, particulates and organic matter is required before the runoff enters any natural water body." Section 5.4.3.2.c reiterates that "runoff shall be routed through swales, drywells, or infiltration ditches and other methods to increase percolation, allow suspended solids to settle and remove other pollutants." Vegetative strips are also required between wetlands and urban development, with the required distance depending upon the type of development. Distances range from 20 feet (single-family residential) to 50 feet (commercial, industrial, or multifamily residential) (CDM, 1998).

Modified Extended Dry Retention Pond

This pond includes a small micro-pool that promotes some removal of dissolved pollutants and particular nutrients. Upstream of the micro-pool, runoff is detained and drawn down slowly as in an ordinary extended dry detention pond. The removal efficiency is expected to be similar to a wet detention pond (CDM, 1998). The Beaufort County BMP manual recommends these systems for types A or B soil because of their higher infiltration capacities. However, dry retention ponds are more susceptible to re-suspension of pollutants, may increase mosquito production, and hold little aesthetic value (Schueler, 1987). Additionally, most of the soils in the Okatie basin are type D soils.

Vegetated Submerged Bed Wetlands

These subsurface treatment wetland systems function by having both aerobic and anaerobic zones and treat by contact filtration and epilitic algal adsorption that are attached to the rock media. This newer technology may be part of a treatment train downstream of a wet detention system for example. Primary study results show results of 78% FC, 82% TP, 81% TSS and 63% TN removal rates from a 121-acre industrial watershed in Central Florida (Egan et al., 1995).

Street Sweeping

Street sweeping has largely fallen out of favor as a BMP due to the National Urban Runoff Program (NURP) which concluded that street sweepers were not very effective in reducing pollutant loads (EPA, 1983). This may be due to the older sweepers inability to collect fine sized particles. The fine-sized particles tend to have a high proportion of pollutants attached due to the large surface-to-volume ratio that allows for higher adhesive properties. Even with the more efficient sweepers, this BMP is only recommended in high-density areas with large amounts of imperviousness due to the large amount of wash-on that would occur during rain events that would make the cleaned streets inconsequential.

6.2 Jasper County Stormwater Ordinance

The potential increase in pollutant loadings from Jasper County in to the Okatie River could be significant due to the current zoning of the properties (commercial) and the lower stormwater treatment requirements. It is recommended that Jasper County adopt Beaufort County's criteria for stormwater treatment as contained in the Beaufort County Manual for Stormwater Best Management Practices. Jasper County Development Review ordinances should be developed or modified to require the treatment criteria contained in the Manual.

6.3 Septic System Minimization

Discharge of domestic sewage that may occur from area septic systems (and from leaking sanitary sewers) enriches the water's nutrient load with dissolved and suspended materials containing high levels of nitrogen, potassium, and phosphorus (the three most important ingredients of commercial fertilizers). These discharges contain not only nutrients that encourage eutrophication, but also coliform bacteria, pathogenic viruses and substances that deplete oxygen in the water. Leaking and ineffective septic systems are considered to account for 66% of the groundwater problems that have been detected in coastal environments (Cofer-Shabica, 1999). Additionally, the reported national septic failure rate is about 10% (CWP Concentrations, 1999).

Septic systems should not be allowed within 200 ft of the Critical Line (areas at or below the mean high tide that are periodically inundated with saline water). Additionally, there should be at least an 18-inch vertical separation between the bottom of the septic tank tile field and groundwater (Cofer-Shabica, 1999).

Almost all homes adjacent to shellfish waters in Area 18 are served by individual sewage treatment and disposal systems (ISTDSs). Soils in most areas are considered to be suitable for ISTDSs and systems should operate properly if maintained. However, many older homes with "grandfathered" systems may not meet current standards (Payne, 2001).

It may be recommended to have existing septic systems be connected to the wastewater treatment plant. Beaufort County, and the county's municipalities, should require the inspection and maintenance of septic systems as per CWTF (1997) and provide financial incentive to do so; SCDHEC should approve system repairs. Secondary and tertiary treatment of domestic sewage is effective in reducing the nutrient load and biological oxygen demand. Because much of the newer developments are connected to a central sewage treatment system, this should minimize impacts in relation to water quality.

6.4 Public Education

Public education should be encompassed in regards to watershed protection. Many people do not realize that much of the bacterial loading problem can come from NPS runoff of fecal material from pets, domestic animals, and local wildlife such as raccoons, other small fur-bearing animals, and birds attracted to non-natural food sources left by humans. When these sources are located close to estuarine habitats, they can result in significant bacterial loading to small drainage areas. Ensuring that trash dumpsters located next to waterways (e.g., at boat landings, etc.) are kept closed, discouraging feeding of birds, eliminating runoff from equestrian and other domestic animal facilities, and removing dog feces using a pooper scooper are just a few ways to reduce bacterial loading from these sources (SCDHEC, 2000).

Research has clearly shown that reductions of NPS runoff must utilize a cumulative risk reduction strategy. For agricultural NPS runoff, this has included methods such as

Integrated Pest Management (IPM), selection of less toxic pesticides, BMPs for tillage and soil conservation and retention ponds. Cumulative risk reduction strategies will be effective in urban areas including reducing the amount of impervious surfaces, use of wetlands, detention basins or retention ponds, BMPs for yards and lawns including amounts and types of fertilizers and lawn care products used, the inclusion of properly designed green space corridors and the planting of trees and other vegetative cover in critical drainage areas near streams. This will require a substantial public education program on the importance of urban NPS runoff control and how stormwater utilities can prevent/manage environmental impacts of urban NPS runoff (SCDHEC, 2000).

Educational kiosks, storm drain markers, and possible advertising campaign could be implemented. Common source control programs implemented may include pet waste cleanup, proper disposal of kitty litter, pump-outs of boat sewage, septic system maintenance, discouraging waterfowl in detention ponds, and general urban house cleaning. A 1982 study of Baltimore alleys found that bacterial levels were generally lower in well-maintained alleys compared to alleys in poor condition (CWP, 1999).

This educational effort should be geared at both the new homeowner and at retrofitting existing residential areas and possibly at regional facilities kiosks (if implemented). A review of BMPs currently used for golf courses in the region may also be appropriate, so as to evaluate and routinely (e.g., every 5 years) update these BMPs on a regular basis. This could be coordinated with the public information function of the Beaufort County Stormwater Utility.

6.5 Hydrologic Restoration

The treatment train concept of utilizing various BMPs to treat stormwater runoff would be maximized in the scenario of putting in place as many treatment options as possible. Generally, the most cost-effective BMP would be to restore the original hydrology of wetlands and allow the natural processes to treat the surface runoff in areas where possible. This may be done in two areas of the Okatie watershed at the eastern tributary of the Okatie and on Property 5 of regional facilities locations.

Eastern Tributary

This tributary of the Okatie River is an area of past wetland degradation from dredging and ditching that was likely done for silviculture purposes. This once expansive riparian forested swamp would be an area that should have the hydrology restored to mitigate for the urban development that will be occurring in the peripheral areas. Currently the portion of the eastern tributary comprises approximately 257 acres of forested wetlands. It is roughly estimated (by ArcView aerial photo estimation) that an additional 145 acres may be hydrologically restored and that the total forested swamp area would be increased to 402 acres (see Figure 6-4).

If new development in this area utilized the 100-ft buffer zones as a BMP then this area's ability to treat pollution from runoff would be augmented (see 6.1.1, Headwater Buffers). Buffer modeling results show that this BMP could reduce pollutants from future residential sources by 13-20% in the northeast corner of this area (Catchment 79) (see Appendix 3d, Figures 3d-1 through 3d-5, and Tables 3d-19 and 3d-20). The rest of the area would experience pollution reduction of 16-25% (Catchments 78 and 73). All of these catchments were determined to be relatively high total, and area-normalized, sources of all pollutants under FLU conditions (see Appendix 3a, Figures 3a-1 through 3a-10, and Tables 3d-14 and 3d-15). Catchment 73 was the only exception to these results, being only a medium area-normalized source of FC and Zn.

Properties 5 and 6

These properties are primarily recently cleared forested with a drainage path running through the middle of Property 5 (see Figure 5-4). It is apparent from comparison of the NWI classification and the 1994 and 1999 aerial photos that the swamp slough was impacted by clearing and ditching. Vegetation and color signature indicate an excess of water west of the berm, indicating a dam/reservoir effect, whereas land to the east indicates a suppression of hydric conditions. Additionally, a small road on the border of Properties 5 and 6 appears to impede water flow to the downstream ditch. Furthermore, the expansion of Highway 278 had cut through approximately 5.9 acres in the northwest portion of the property which was originally part of the NWI inventoried swamp wetland. This is labeled in the key as Wetlands Lost. This once expansive riparian forested swamp would be an area that should have the hydrology restored to mitigate for the urban development that will be occurring in the peripheral areas. Currently that portion of the properties comprises approximately 13.2 acres of forested wetlands. It is roughly estimated that an additional 28.6 acres may be hydrologically restored and that the total forested swamp area would be increased to 41.8 acres by ArcView aerial photo estimation (see Figure 6-5). The additional wetland area as labeled on Figure 6-2 may act as a wetland creation area that may require minimal earth moving.

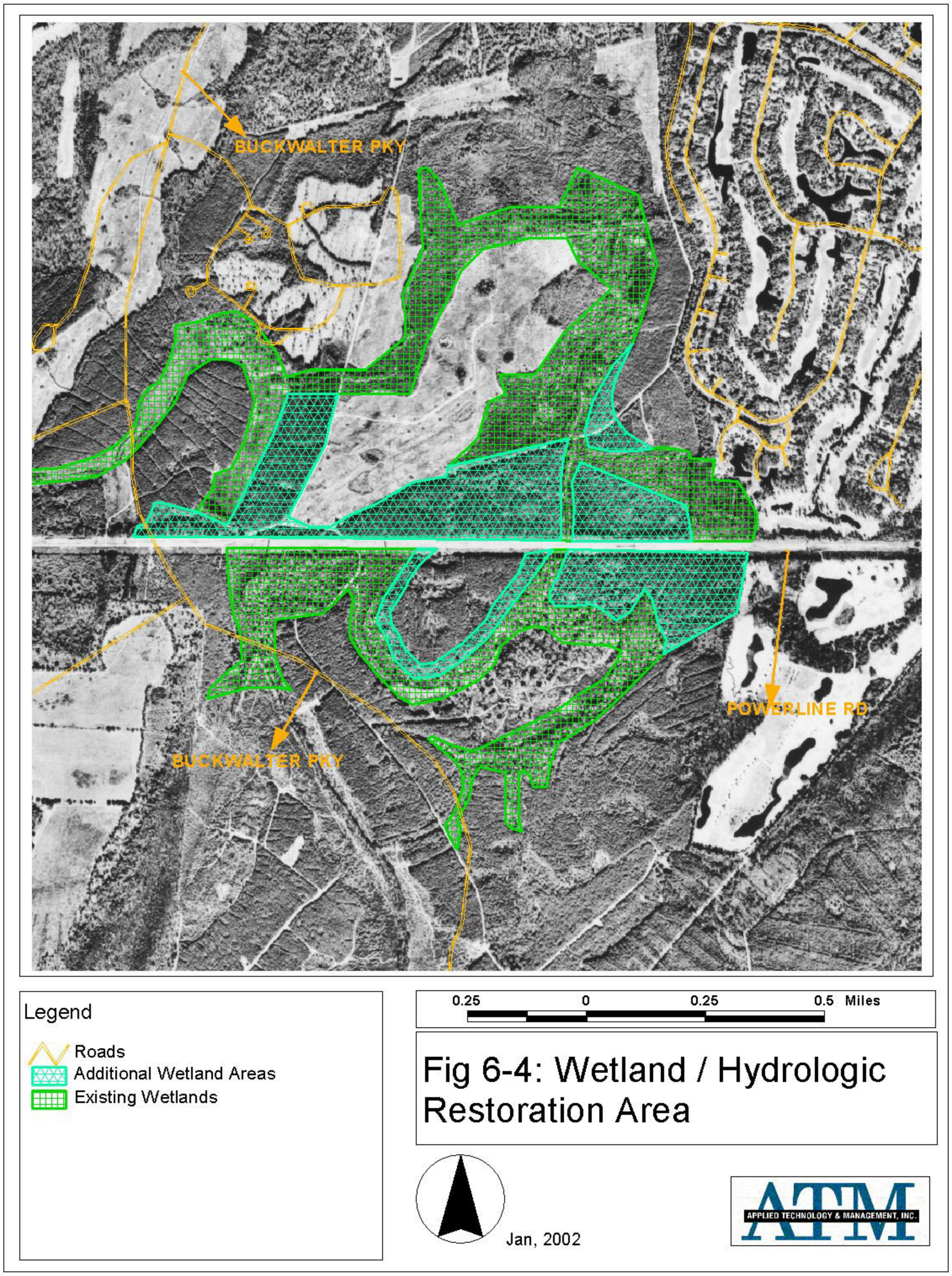


Fig 6-4: Wetland / Hydrologic Restoration Area

In addition to the water quality improvements, the regional facility properties and hydrologic restoration areas may be utilized for low-impact parks with nature trails, boardwalks and wildlife viewing areas, and recreational facilities. Educational kiosks and interpretive signage may provide an informative educational component to the region on the importance of wetlands, stream corridors and their linkage to the estuarine system.

If new development utilized the 100-ft buffer zones as a BMP, then this area's ability to treat pollution from runoff would be augmented as well (see 6.1.1-Headwater Buffers). A similar effect would be seen if the buffers were incorporated into the restoration on the property. Under FLU conditions, residential development will bound the existing wetland feature on the southern portion of the site as well as restored wetland areas on the easternmost portion of the site (see Figure 6-5). Residential runoff will contribute increasing levels of pollutants to this low-lying area, which is hydrologically connected to the Okatie River. Modeling results show that Catchment 12, which contains Properties 5 and 6, is a medium to high total and normalized source of pollutants and will continue to be so under future land use conditions (see Appendix 3a, Figures 3a-1 through 3a-10, and Tables 3d-14 and 3d-15). Buffer modeling results show that buffers placed on the existing southern wetland area would decrease pollutant loading from Catchment 12 by 2-4% (see Figure 6-3, Appendix 3d, Figures 3d-1 through 3d-5, and Table 3d-21). However, if additional wetlands being restored in this area were buffered as well pollution reduction would increase.

6.6 Regional Facilities

Regional Facility Properties 1 and 2 should be investigated, and if plausible, implemented to enhance existing treatment capabilities in the area and address the current pollutant issue.

To address future pollutant issues, Regional Facilities 4, 5, 6, 7, and 8 should be implemented if the Jasper County stormwater treatment requirements cannot be raised to the level of those in Beaufort County.

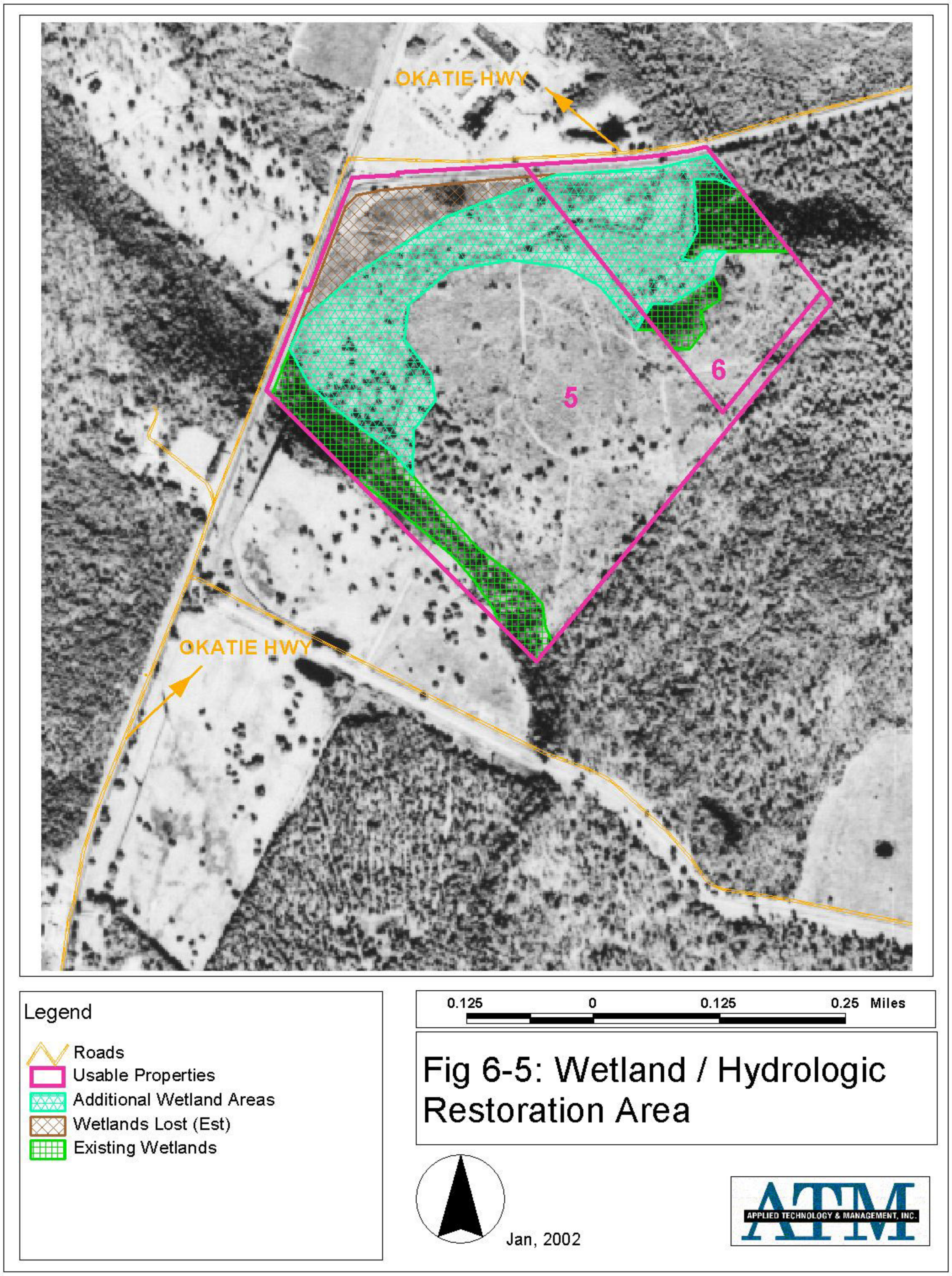


Fig 6-5: Wetland / Hydrologic Restoration Area

7.0 WATERSHED MANAGEMENT PLAN IMPLEMENTATION

7.1 Operations and Maintenance

The current level of operation and maintenance should be maintained throughout the Okatie River watershed. Annual inspection of existing culverts and ditches upstream of culverts should be done to ensure siltation and/or excessive vegetation does not impede flow of stormwater. Care should be taken to not indiscriminately dredge and herbicide all vegetation as hydrophytic vegetation plays an integral role in water quality treatment.

7.2 Monitoring

Currently, SCDHEC EQC Bureau of Water has a monitoring program for Shellfish Management Area 18 that encompasses the Okatie River Watershed. This monitoring program is updated annually and focuses on FC. SCDHEC Bureau of Water Monitoring, Assessment and Protection Division also has a database that maintains records of past water sampling in the watershed that encompasses the following parameters:

- Salinity
- Temperature
- FC
- NO2/3
- NH3/4
- TKN

Additional recommended elements of the monitoring program include the following:

1. First flush effect. Higher concentrations of pollutants are often observed in the first runoff from a storm, a phenomenon referred to as *first flush*. This is especially true for dissolved components, including nutrients, organic lead, and ionic constituents (NCTCG, nd). Additionally, Section 4.2 addresses this issue relevant to FC. Therefore, a monitoring program should include a program to sample specific locations within a specific time (~30 minutes after initial rainfall). Antecedent conditions also should be specified in the monitoring plan because the contaminants build up over time in dry conditions. Therefore, a timeframe such as a 2-week dry period (period with no rainfall events greater than 0.25 inch) should be specified.

2. Develop a list of specific "indicator" parameters based on existing land uses and the anticipated pollutants from stormwater runoff. This will assist in defining improving, as well as degrading, water quality trends and possibly attribute them to a BMP or a defined source or sources (in the event of water quality degradation);

3. Establish monitoring stations at existing stations where long-term or short-term data already exist. Establish additional monitoring stations as needed to characterize each watershed with respect to water quality and use impairment;

4. Include flow measurements as an integral component of the monitoring program;

5. Initiate a more detailed analysis of the existing water quality to detect potential seasonal trends in the violations observed with DO and coliforms. This will potentially lead to a more streamlined approach for implementing BMPs to reduce violation probability.

6. Establish a volunteer monitoring program such as a Watershed Action Volunteer program. Training of volunteers will increase community awareness and involvement. Standardized water sampling equipment and protocols would ensure quality control.

7.3 Funding Sources

Funding options for stormwater management are numerous. Each funding option must be evaluated according to the objectives of (all or part of) the stormwater management program, as well as the option's ability to meet (all or part of) the funding requirements. Any combination of options can likely meet a community's stormwater management funding needs. State and local laws can however, along with public opinion and the local government's attitude, serve to make certain options either more or less suitable.

The principal stormwater funding options available are:

Stormwater Utilities – The development of a dedicated funding source via user fees. This involves the establishment of a utility to assess and collect service charges from property owners based on the demand that her or his property places on the stormwater management system. Fees charged by stormwater utilities can be assessed in various fashions, with rates calculated on the average characteristics of property types and related impact, the easiest to administer. Beaufort County recently passed their stormwater utility ordinance.

Stormwater Revenue Bonds – Similar to other municipal bonds, stormwater bonds provide monies for capital expenses. Typically, these bonds are issued in conjunction with the establishment of a stormwater utility that will provide the funding to pay back the bonds.

319(h) Nonpoint-Source Implementation Grants – Administered through state government, *these* grant funds are to be used on programs and projects in accordance with Section 319(h) of the Clean Water Act. These grants require a minimum 40% local match.

Clean Water State Revolving Loan Fund – Low interest loans available to local governments for capital projects, major equipment, and associated engineering costs. Loan terms are limited to 20 years.

Community Development Block Grant Funding (CDBG) – Federal monies administered by the states directed to low- and moderate-income communities for capital improvements. These grants require a minimum 25% local match.

Hazardous Mitigation Grant Program – Federal funding available to state and local governments to reduce or eliminate the long-term risk to human life and property from the effects of natural hazards. These grants require a minimum 25% local match.

There are other non-traditional stormwater funding that can be pursued, particularly in the form of federal grants and loans. Each funding source must be investigated thoroughly prior to application to determine its projected continual availability, required upfront activities, and the funding agency's stormwater-related acceptance history.

7.4 Implementation Schedule

The recommended schedule for implementing the recommendations listed in Section 6 is as follows:

1. Jasper County Development Review and Ordinance Modification: This should begin immediately before significant development occurs in the area adjacent to State Road 170.

2. Property Acquisition: This process should be initiated in the next 6 months. Since it is desirable to avoid condemnation proceedings, it is recommended to find "willing sellers" soon.

3. Public Education: This process should be initiated within 6 months. This requires coordination with the Beaufort County Stormwater Utility

4. Hydrologic Restoration: Initiate discussions with the appropriate developers regarding the feasibility of implementing the two wetland restoration projects discussed above within 6 months since these areas are already in the planning stages.

5. Initiate an engineering study for the design and implementation of Regional Facility 1 in 1 year.

6. BMP Manual Modification: This should be performed within 2 years.

7. Septic System Inspections: A program for inspecting septic systems located along the Okatie River, or its tributaries, should be initiated within 2 years.

8. Regional Facilities: Except for Regional Facility 1 listed above, engineering studies to evaluate implementation of these concepts should be initiated if stormwater treatment requirements in Jasper County are not improved to the recommended levels. This should be initiated following the outcome of the ordinance initiative.

8.0 SUMMARY

Urban stormwater practices must be extremely efficient if they are to produce storm outflows that meet the 14 MPN standard for FC bacteria from a site. The national mean of 15,000 MPN would require a stormwater practice to achieve a 99% removal rate for FC to meet the standard. To date, performance-monitoring research has indicated that no storm-water practice can reliably achieve a 99% removal rate of any urban pollutant on a consistent basis (Schueler, 2000b). Even an advanced secondary wastewater treatment that filters its effluent still discharges FC between 1,000 and 100,000 MPN/100mL before final chemical disinfection (ASCE, 1998). Therefore a treatment train of several BMPs in-line may be required as the Okatie watershed becomes built-out. BMPs should emphasize control of freshwater inflow in headwater areas of estuarine drainage systems.

The water quality data require a monitoring program at key tributary sections during the first flush effect from significant storm events (~>0.75"/day) to better pinpoint FC and other contaminant hotspots. Because FC concentration is proportional to such factors that include salinity, antecedent conditions, population density, and VSS, a standardized monitoring program should be established. The program should include monitoring of the influent/effluents of in-situ retention and detention systems. Regional facilities should be considered for buffer/conservation areas before the watershed is built-out. Additionally educational efforts with landscape xeriscaping and golf courses practices should be done. A citizen volunteer program should be established to give the community a sense of ownership and connectedness to their environment.

9.0 REFERENCES:

American Society of Civil Engineers (ASCE). 1998. Design of Municipal Wastewater Treatment Plants. 4th ed. Vol.2 American Society of Civil Engineers Manual and Report on Engineering Practice No. 76. WEF MOP #8.

Applied Technology and Management, Inc. (ATM). Feb. 1999. Evaluation of Stormwater Quality for the Proposed Barefoot Landing Resort.

Batiuk, R.A., R.J. Orth, K.A. Moore, W.C. Dennison, J. C. Stevenson, L.W. Staver, V. Carter, N.B. Rybicki, R.E. Hickman, S. Kollar, S. Bieber, P. Heasly. 1992. Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis. EPA: Annapolis, MD.

Beaufort County May 1995. Stormwater Management Master Drainage Plan for Beaufort County.

Beaufort County: Code of Ordinance. 2002. Part II, Chapter 106, Article XIII, Division 4, Sec 106-2860 General Planning and Design Requirements.

Bingham, D. R., F.X. Doughrety, S.L. MacFarlane. 1996. Successful Restoration of Shellfish Habitat by Control of Watershed Pollution Sources. EPA 1996 Watershed Proceedings.

Borden, R. C., J.L. Dorn, J.B. Stillman, S. K. Liehr. Sept. 1997. Evaluation of Wet Ponds for Protection of Public Water Supplies. WRRI. NCSU Report NO. 311.

Cake, E.W., Jr. 1983. Habitat Suitability Index Models: Gulf of Mexico American Oyster. U.S. Dept Int. FWS. FWS/OBS-82/10.57. 37 pp.

Camp Dresser and McKee (CDM). March 1998. Beaufort County Manual for Stormwater BMPs.

Chestnut, D. Apr. 21 1999. Memorandum Eagle Pont PUD Stormwater/Water Quality Monitoring Data. SCDHEC Water Quality Monitoring Section.

Clean Water Act, Chapter 26, "Water Pollution Prevention and Control," Title 33 U.S.C. §§ 1251-1387Clean Water Task Force (CWTF). Feb. 1997. Final Report A Blueprint for Clean Water: Strategies to Protect and Restore Beaufort County's Waterways.

Cofer-Shabica S. V. 1999. Summary of Findings and Recommendations of the Workshops on Beaufort County's River Quality Overlay District Ordinance.

Connell, D.W., and G.J. Miller. 1984. Chemistry and Ecotoxicology of Pollution. John Wiley & Sons, NY.

Department of Commerce, National Oceanic and Atmospheric Administration Coastal Services Center. Charleston, SC. NOAA CSC /7-96/001.

Dudas, J.S. 2000. Evaluation of Effects of Urbanization and Spatial Wetland Configuration Effects on Southeast Florida Hydrology and Water Quality Using a Dynamic Spatial Model. Thesis. University of Florida.

Egan, T., J.S. Burroughs and T. Attaway. 1995. Packed Bed Filter. Proceedings of the 4th Biennial Research Conference SWFWMD. Brooksville, FL. pp. 264-274.

Environmental Protection Agency (EPA). March 2000. Stormwater Phase II Compliance Assistance Guide. EPA 833-R-00-002.

Federal Interagency Stream Restoration Working Group. Oct. 1998. Stream Corridor Restoration (Principles, Processes, and Practices).

Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration: Principles, Processes, and Practices.

Harper, H.H. Oct 19-20, 1995. Pollution Removal Efficiencies for Typical Stormwater Management Systems in Florida. Stormwater Research Conference.

Hernandez, D., W. Reyn, and L. Hajjan. nd. Vegetated Riparian Buffers and Buffer Ordinan ces. South Carolina Department of Health and Environmental Control (SCDHEC) Office of Ocean and Coastal Resource Management (OCRM) Publication.

Horsley, S. W. 1995. The StormTreat System – A New Technology for Treating Stormwater Runoff. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 304-305.

Kadlec and Knight. 1996. Treatment Wetlands. Lewis Publishers.

Kennish, M.J. 1992. Ecology of Estuaries: Anthropogenic Effects. CRC Press, Inc., Boca Raton, FL.

Knopf, A.A. 1977. The Audubon Society Field Guide to North American Birds (Eastern Region).

Livingston, E.H. 1989. The use of wetlands for urban stormwater treatment. Design of urban runoff quality controls. ASCE, New York, NY.

Lopez, A.L. 2000. Water Quality Monitoring Program Eagle ‘s Point PUD Annual Summary Report Spring 2000. Thomas and Hutton Engineering CO.

Lores, E.M. and J.R. Pennock. 1988. Effect of Salinity on Binding Cd, Cr, Cu, and Zn to Dissolved Organic Matter. Chemosphere 37(5):861-874. ERL 6B3968).

McCutcheon, S. C. Oct. 1999. Riparian Buffer Lengths Necessary to Control Sediment Eroded from Prevalent Beaufort County Soils. Hydrologic and Environmental Engineering.

Mueller, J.A., and R.V. Thomann. 1987. Principles of Surface Water Quality Modeling and Control. Harper & Row Publishers, NY.

National Oceanic and Atmospheric Administration and Environmental Protection Agency (NOAA/EPA). 1988. Strategic Assessment of Near Coastal Waters, Chapter 3, Susceptibility and Concentration Status of Northeast Estuaries to Nutrient Discharges. NOAA, Washington, D.C.

Nautical Software, Inc. 1997. Tides and Currents Pro Version 2.5b for Windows. Beaverton, OR.

North Central Texas Council of Governments (NCTCG) Department of Environmental Resources. nd. Guidance for Post-Construction Highway Runoff Management.

Paerl, H.W. 1993. Emerging Role of Atmospheric Nitrogen Deposition in Coastal Eutrophication: Biogeochemical and Trophic Perspectives. Can J. Fish. Aquat. Sci. Vol. 50:2254-2269.

Paulson, A.J., R.A. Feely, H.C. Curl, Jr., and D.A. Tennant. 1989. Estuarine Transport of Trace Metals in a Buoyant Riverine Plume. Estuarine, Coastal and Shelf Science 28:231-248.

Payne, D. 2001. DHEC Shellfish Management Area 18 Annual Update.

Say–Hua Lim. 1982. Sources of Microorganisms in Urban Runoff. Masters Thesis, Johns Hopkins University.

Schueler, T. 1995. Environmental Land Planning Series: Site Planning for Urban Stream Protection. Publication # 95708. Center for Watershed Protection. Elliot City, Maryland. 232pp.

Schueler, T. R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, DC.

Schueler, T.R. 1992. Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region. Metropolitan Washington Council of Governments, Washington D.C.

Schueler, T.R. 2000a. Developments in Sand Filter Technology to Treat Stormwater Runoff, Article 105 in The Practice of Watershed Protection. Center for Watershed Protection.

Schueler, T.R. 2000b. Microbes in Urban Watersheds: Ways to Kill 'Em, Article 67 in The Practice of Watershed Protection. Center for Watershed Protection.

South Carolina Department of Health and Environmental Control (SCDHEC). December 1997. Watershed Water Quality Assessment for the Savannah and Salkehatchie River Basins, Bureau of Water, Technical Report No. 003-97.

South Carolina Department of Health and Environmental Control (SCDHEC). Feb 1997. South Carolina Stormwater Management and Sediment Control Handbook for Land Disturbance Activities.

South Carolina Department of Health and Environmental Control (SCDHEC). Spring 1994. Stormwater Permitting in South Carolina.

South Carolina Department of Health and Environmental Control, South Carolina Department of Natural Resources, and National Ocean Service.(SCDHEC, SCDNR, and NOAA). 2000. Final Report: A Baseline Assessment of Environmental and Biological Conditions in Broad Creek and the Okatie River, Beaufort County, South Carolina.

South Carolina Department of Natural Resources and U.S. Department of Commerce, National Oceanic and Atmospheric Administration Coastal Services Center and National Geophysical Data Center. 1996. Ecological Characterization of Otter Island, South Carolina: A Prototype for Interactive Access to Coastal Management Information.

Stevens, M.T. Dec. 1999. Sweetwater Branch Stream Restoration Design. M.E. project. Department of Environmental Engineering Sciences, University of Florida.

Stormceptor Canada, Inc. 1997. Stormceptor Technical Manual. Etobicoke, Ontario, Canada.

Strynchuk, J., J. Royal and G. England, P.E. 1997. The Use of a CDS Unit for Sediment Control in Brevard County. Brevard County Surface Water Improvement Executive Summary.

Tillis, G.M. 1996. Development of a GIS Model Evaluating Stormwater Wetland Treatment. Master's Project, University of Florida, Gainesville, FL.

University of Maryland Center for Environmental Science Chesapeake Bay (UMCES) June 2001. Water Quality Monitoring Program Ecosystem Processes Component Level One Report #18. Maryland DNR.

Viessman, W. and M.J. Hammer. 1993. Water Supply and Pollution Control, Fifth Edition. Harper Collins College Publishers.

Water Environment Federation. 1992. Manual of Practice FD-20/ American Society of Civil Engineers Manual of Practice No. 77 Design and Construction of Urban Stormwater Management Systems.

Watershed Protection Techniques. April 1999. Microbes and Urban Watersheds III. Volume 3, No.1, pp 554-574.

Watershed Protection Techniques. April 1999. Technical note #104 Vol. 3, No.1, pp 605-608. Performance of a Proprietary Stormwater Treatment Device -- The Stormceptor®.

White, N. M., D.E. Line, J.D. Potts, W.K. Smith, B. Doll, W.F. Hunt. 2000. Jump Run Creek Shellfish Restoration Project. Journal of Shellfish Research. Vol. 19, NO. 1. 473-476.

Wong, T.H. 1999. Continuous Deflective Separation: Its Mechanism and Applications. Department of Civil Engineering, Monash University.